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FINAL DRAFT REPORT

EVERGLADES PROTECTION PROJECT

Contract C-3051, Amendment 2

PHASE I EVALUATION OF ALTERNATIVE TREATMENT TECHNOLOGIES

Submitted to:

SOUTH FLORIDA WATER MANAGEMENT DISTRICT

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BROWN AND CALDWELL
CONSULTANTS

In Association With:

Mock, Roos & Associates, Inc.

Applied Technology and Management, Inc.

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EXECUTIVE SUMMARY

In March 1992, the Governing Board of the South Florida Water Management District (District) adopted the Everglades Surface Water Improvement and Management (SWIM) Plan consistent with a Settlement Agreement between the United States, the Florida Department of Environmental Regulation, and the District. The primary objective of the SWIM Plan is to reduce phosphorus discharges from the Everglades Agricultural Area (EAA) while maintaining suitable hydroperiod in water conservation areas and the Everglades National Park. In addition to a comprehensive research and monitoring program, the present SWIM Plan provides for (1) the construction and operation of four large-scale Stormwater Treatment Areas (STAs), which are constructed wetland systems designed to treat stormwater runoff for the removal of nutrients, and (2) the initiation of a regulatory program having as its goal the reduction of total phosphorus loads currently discharged from the EAA by 25 percent. The regulatory program is to include the development and implementation of best management practices (BMPs) for stormwater runoff control by property owners within the EAA.

In approving the SWIM Plan, the District's Governing Board also committed to minimizing the economic impacts on the area by continuing to consider other nutrient and stormwater runoff control alternatives that could satisfy the mandated performance requirements of the Settlement Agreement. Brown and Caldwell was selected to assist the District in the evaluation of alternative treatment technologies for possible incorporation into the SWIM Plan either in conjunction with, or in place of, the wetland systems currently proposed. This report presents the results of our initial evaluation of 16 alternative treatment technologies that were suggested by various agencies, organizations, companies and individuals as having applicability for removing phosphorus from EAA stormwater runoff.

OBJECTIVE OF THE EVALUATION

The objective of this initial evaluation of alternative treatment technologies is to identify those technologies which have demonstrated capability to reliably satisfy the phosphorus reduction requirements of the SWIM Plan on a cost-effective basis, and to screen out those technologies that currently do not have that capability. In accordance with the evaluation methodology approved by the District, the investigations performed were designed to define the alternative treatment technologies only to the point that the economic and noneconomic issues associated with their implementation in the EAA could be identified and a comparative evaluation of their advantages and disadvantages could be made. Detailed evaluation of those treatment technologies selected as a result of this initial screening process will include development of a conceptual engineering design for each alternative. This will be accomplished in a subsequent phase of work.

EVALUATION METHODOLOGY

The methodology followed for the evaluation of treatment technologies was presented in the Amendment 1 report entitled "Evaluation of Alternative Treatment Technologies--Evaluation Methods and Procedures," submitted to the District by Brown and Caldwell in September 1992. The evaluation methodology consists of two phases: (1) a Phase I screening evaluation in which the various treatment technologies are rated against a set of general criteria at four scales of application and three levels of phosphorus reduction, and (2) a Phase II evaluation in which the top rated technologies from the Phase I evaluation will be analyzed in more detail against an expanded set of evaluation criteria. This report documents the results of the Phase I screening evaluation.

Basis of Evaluation

Not all of the treatment technologies proposed for the EAA may be applicable at the basin scale as direct alternatives to the STAs. Some technologies may be much more economical or effective at a smaller scale or for treating discharges from point sources rather than drainage waters from agricultural fields. Consequently, the Phase I evaluation considered four different scales of technology application: (1) basin scale, accommodating flows from the S-5A, S-6, S-7 and S-8 basins; (2) subbasin scale, accommodating flows from groups of farms or designated drainage districts; (3) farm scale, accommodating flows from a single farm operation or a group of small farms; and (4) point source scale, focusing on discharges from sugar mills.

It is also recognized that the various treatment technologies proposed for the EAA may not all be capable on their own of achieving the long-term average goal of 50 parts per billion (ppb) total phosphorus (TP) in discharges to the water conservation areas (WCAs). Some technologies may be efficient at achieving a portion of the mandated reduction in phosphorus loading and can be used effectively in combination with other technologies to achieve the 50 ppb goal. Such technologies should not be eliminated from further consideration solely on the basis of not being able to reduce average phosphorus concentrations to 50 ppb on their own. Consequently, the Phase I evaluation considered three levels of phosphorus reduction capability: 25, 50, and 75 percent, all based on expected TP concentrations following implementation of on-farm BMPs. The 75 percent reduction capability is intended to indicate that a technology can achieve the 50 ppb TP goal.

Evaluation Criteria. A set of nine criteria was used in the Phase I evaluation of alternative treatment technologies. These criteria are presented in Table 1. The criteria were selected because they represent a broad cross-section of considerations which must be addressed in the formulation of a phosphorus reduction program for the EAA and because they can be applied generally to the alternative technologies during the screening process without site-specific information on how the technologies are to be implemented.

Rating of Alternatives. A numerical scoring system was used to facilitate the comparison of technologies against the common set of evaluation criteria. The scoring system had two components: technology rating and criterion weighting. Technology ratings were used to numerically compare alternatives according to a single criteria. The ratings ranged from "10" for the most positive or favorable condition to "1" for the least positive or favorable condition. Criterion weights were used to compare the importance of one criterion in relation to other criteria. An individual criterion was assigned a weighting factor ranging from 1 to 3, reflecting its relative importance in satisfying the goals and objectives of the SWIM Plan. The weighting factors for each criterion are presented in Table 1. Multiplying the technology rating for a criterion by the weight of the criterion yielded the score for that technology against that criterion. Addition of the scores for all criteria yielded the total score for a technology.

Table 1 Phase I Evaluation Criteria

Criterion	Criterion weighting
Phosphorus removal capability	3
Implementation schedule	2
Hydroperiod impact	2
Operational impact on C&SF project	2
Permitting requirements	2
Previous application of technology	2
Capital cost	1
O&M requirements	1
Economic impacts	1

The total scores for the various technologies at each of the four scales of application (basin, subbasin, farm, point source) and phosphorus removal levels (25, 50, and 75 percent) were compiled and a comparative evaluation of the technology ratings was made. For each scale of application, technologies with the highest ratings were recommended for further evaluation in Phase II.

Scales of Technology Application

As indicated previously, the Phase I evaluation of alternative treatment technologies was carried out at four different scales of application: basin, subbasin, farm, and point source. Each of these scales of application is briefly defined below.

Basin Scale. Basin scale refers to the four large drainage basins tributary to the S-5A, S-6, S-7, and S-8 pumping stations. The STAs, currently proposed in the District's SWIM Plan, have been conceptually designed at the basin scale. In this Phase I evaluation, a typical basin is characterized as the average of the four basins in the EAA.

Subbasin Scale. Subbasin scale refers to a group of farms or a drainage district within a basin. For the purpose of this Phase I evaluation, it is assumed that there are ten typical subbasins within a typical basin for a total of 40 subbasins within the EAA.

Farm Scale. Farm scale refers to a single farm or group of small farms discharging directly to primary canals in the EAA. It is estimated that there are 250 or more individual farm discharges in the EAA. However, according to District records, there are 173 permitted discharges, some of which involve multiple discharge points. For this Phase I evaluation, it was assumed that there are 173 typical farm scale treatment facilities required in the EAA.

Point Source Scale. Point source scale refers to any discharge from the seven sugar mills in the EAA. The discharges from these sugar mills were the focus of point source evaluation since the waste management practices of the mills have the potential to discharge significant quantities of phosphorus into the groundwater and, eventually, into the primary canal system.

Wastewater Flows and Phosphorus Concentrations

Table 2 summarizes the wastewater flows and phosphorus concentrations that were used in the Phase I evaluation of alternative treatment technologies. Flows for the basin, subbasin, and farm scales were derived from basin scale data for the period 1979 to 1988 presented in the draft report prepared by Burns & McDonnell entitled "Everglades Protection Project--Conceptual design of Stormwater Treatment Areas (March 1992). Flows for point sources were approximated from a review of Florida Department of Environmental Regulation (FDER) operating permits for the seven sugar mills in the EAA. A detailed description of how the various flow parameters were calculated is presented in Chapter 2 of this report.

Table 2 Wastewater Flows and Phosphorus Concentrations Used in the Phase I Evaluation of Alternative Treatment Technologies

Evaluation parameter	Scale of application			
	Basin	Subbasin	Farm	Point source
Wastewater flow, mgd				
Average annual	183	18	3	10
Maximum month	743	74	13	15
Peak	2,330	233	33	20
Phosphorus concentration				
Total P, mg/l	0.15	0.15	0.15	1.0
Soluble P, percent	75	75	75	100
Insoluble P, percent	25	25	25	0

Water quality data collected by the District at the four primary pumping stations indicate that TP concentrations over the period 1979 to 1988 ranged from about 0.1 milligrams per liter (mg/l) for Basin S-7 to about 0.2 mg/l for Basin S-5A. The flow weighted average TP concentration over the four primary basins in the EAA was determined to be about 0.15 mg/l. This concentration was used as the average influent TP concentration for evaluation of alternative treatment technologies at the basin, subbasin, and farm scales. Data on phosphorus fractionation was found to be limited. For this preliminary evaluation, it was assumed that 75 percent of the TP was in the soluble form and that 25 percent was insoluble.

Review of monthly monitoring reports from several of the sugar mills in the EAA indicates that effluent TP concentrations vary tremendously, from less than 0.1 mg/l to more than 5 mg/l. Most mills have installed percolation ponds or other facilities to treat process water prior to its discharge. For the purposes of this evaluation, it was assumed that the typical pretreated discharge from a mill contains about 1 mg/l TP and that it is all in the soluble form as might be expected in the effluent from percolation ponds or settling basins.

Sizing of Treatment Facilities

To provide for a fair and objective comparison of alternative treatment technologies, criteria similar to those used in the conceptual design of the STAs were used to size treatment units in this Phase I evaluation. However, some technologies have the capability to achieve much lower effluent phosphorus levels than do others. Consequently, to achieve the same overall water quality goal (i.e., 50 ppb TP), treatment units for technologies capable of achieving very low effluent TP concentrations can be sized to treat less flow and bypass more flow than treatment units that cannot achieve such low effluent TP concentrations. Based on an analysis of daily flow and phosphorus discharges from the EAA and the effluent phosphorus concentration attainable, the sizes of treatment units required for each technology to achieve 25, 50, and 75 percent load reductions were computed. A detailed discussion of the methodology used in sizing treatment units for this Phase I evaluation is presented in Chapter 2 of this report.

Basis of Cost Estimates

Planning level capital cost estimates were prepared as part of this Phase I evaluation to allow a general comparison of initial implementation costs between alternative treatment technologies and the wetlands treatment technology (STAs) currently contained in the District's SWIM Plan. With the exception of the STAs, the cost figures presented in this report were not based on site-specific application of technologies. This will be accomplished in the more detailed Phase II evaluation of treatment alternatives. Care was taken throughout the cost estimating process to apply consistent judgment and assumptions, and as a result, the estimates prepared reflect differences between alternatives, relative to one another. However, because many of the technologies being considered in this Phase I evaluation are in conceptual form at this stage and have not been fully defined, the capital cost estimates presented herein can be expected to have an accuracy no greater than plus or minus 50 percent.

All construction cost estimates were adjusted to August 1992 dollars using an Engineering News Record Construction Cost Index of 5032. Land costs were assumed to average $2,750 per acre across the EAA. Engineering, legal and administrative costs were estimated at 15 percent of total construction cost, plus contingencies, but exclusive of land costs.

ALTERNATIVE TREATMENT TECHNOLOGIES

Sixteen alternative treatment technologies were considered in this Phase I evaluation for reducing phosphorus discharges from the EAA. These technologies are identified and briefly described below. A summary of their primary advantages and disadvantages is presented in Table 3. Detailed descriptions of the technologies, and the bases on which they were evaluated, are presented in Chapter 3 of this report.

Table 3 Summary of Treatment Technologies Considered in the Phase I Evaluation

Technology	Primary advantages	Primary disadvantages	Applicability to the EAA
Chemical Treatment	• Demonstrated technology • Can achieve low P concentrations under controlled conditions • Relatively low land requirements • At farm scale, can be implemented with existing farm equipment	• P removal performance in EAA ditches and canals not documented • Generates sludge for disposal • Possible changes to effluent water chemistry could adversely impact sensitive Everglades vegetation • High level of operational attention necessary	• Field testing in the EAA needed to determine P removal performance • Could be used to complement or enhance the P removal performance of water table management BMPs at farm scale
Limerock sorption	• Uses native limerock material • Can be implemented with farm equipment	• Variability of limerock sorption capacity across the EAA • P removal effectiveness not documented by field testing • Removal and replacement of spent limerock difficult and costly • Projected to require extremely long treatment channels and large land areas to effect the necessary level of P removal	• Limited applicability for selected farm or point source discharges where suitable limerock substrata exists • Appears to be more effective on waste streams with high P concentrations
Sedimentation in limestone borrows	• Capable of improving P removal efficiency of chemical treatment by enhancing sedimentation performance • Many limestone borrows already exist and 300 to 400 acres of additional quarries are constructed annually • Stormwater retention in rock pits already practiced in South Florida's urban areas	• Permitting could require exemption from current FDER regulations • Sludge removal and disposal needed periodically • Potential for contaminating contiguous aquifer • Economically feasible only for drainage area in immediate proximity to the rock pit	• Primary applicability for chemical treatment of discharges from farms located adjacent to existing borrow areas
Percolation ponds	• Proven technology in Florida • Low O&M requirements • Capable of achieving low effluent P concentrations	• Shallow caprock requires horizontal percolation to achieve required P removal • Low adsorptive capacity of EAA muck soils requires prohibitively large levees and pond areas to treat high volume waste streams	• Applicability limited to low volume, high strength waste streams from point sources

Table 3 Summary of Treatment Technologies Considered in the Phase I Evaluation (continued)

Technology	Primary advantages	Primary disadvantages	Applicability to the EAA
Deep well injection	• High P removal capability • Demonstrated technology • Low land requirements • Low O&M requirements	• Injected water is lost for future use • Complicated and lengthy permitting process • Adverse impact on hydroperiod • Widespread implementation by 1997 unlikely	• Applicability probably limited to low volume, high strength point source discharges
Aquifer storage and recovery	• Proven technology • Low land requirements • Low O&M requirements • Potentially significant benefits to water resource management in the region and hydroperiod in the WCAs and ENP	• P removal as a treatment process limited • Complicated and lengthy permitting process; may require FDER exemptions • Widespread implementation by 1997 unlikely	• Primary applicability at basin scale is for water supply; P removal capability limited • For P removal, most applicable at farm scale to reduce drainage discharges
Water Quality/Supply Diversion Plan	• Reduction of phosphorus by diversion of runoff to urban coastal areas for water supply uses	• Storage reservoirs needed for peak flow storage. • Ability to divert sufficient quantity of runoff to result in significant P reduction is questionable • Flow reduction to WCAs may not be offset by reduction in withdrawals from the WCAs • Potential for flooding in the EAA during peak flow conditions and high canal levels in the LEC	• Plan needs to be better defined before costs and benefits to EAA and the region can be assessed
Algal turf scrubbers	• Natural treatment process • Capability to achieve very low effluent P concentrations based on pilot plant results • Land area requirements less than for wetlands	• P removal performance in full scale engineered system has not been demonstrated • Proposed methods for biomass harvesting, processing, and marketing/ disposal have not been tested in the field at any scale	• Full scale testing on EAA runoff needs to be accomplished • Processing and disposal of residual biomass a potentially significant limitation of the technology • Application probably limited to selected farm and point source discharges

Table 3 Summary of Treatment Technologies Considered in the Phase I Evaluation (continued)

Technology	Primary advantages	Primary disadvantages	Applicability to the EAA
Nutrient management system	• Enhanced natural treatment system • Compatible with farm operations and pretreatment facilities at some sugar mills • Less land required than for wetlands	• Proprietary technology--treatment process information not available • Higher O&M than for wetlands • P removal performance not demonstrated on low concentration runoff	• Technology is being pilot tested on sugarcane land in the EAA • Applicability probably limited to selected farm scale and point source discharges
Ozone Treatment	• Commercially available treatment modules • Low land requirements • Low O&M requirements	• Ozone does not remove TP, but can enhance chemical treatment processes • P removal performance not demonstrated on low concentration wastewaters • Proprietary technology--treatment process information not available • No full scale systems in operation • Prohibitive capital costs	• Applicability limited to very low flows and only when chemical addition is used
Sediment dredging	• One-time only treatment process • Implementation can occur quickly • No recurring O&M requirements • Requires that only a small amount of agricultural land be taken out of production for 1 year	• Phosphorus reduction benefits not defined • Potential environmental impacts associated with disposal of dredged materials	• Applicability limited to District canals in this investigation, but could also be applied at farm scale as a BMP • Field studies needed to determine impact of canal sediments on P loads pumped out of the EAA
Wetlands	• Natural treatment process • Demonstrated technology • Treatment benefits other than P removal (N, etc.) • Permitting process for STAs already underway • Low O&M requirements	• Large amount of agricultural land must be taken out of production • Consistent and reliable satisfaction of SWIM Plan P reduction goals is questionable • Treatment life of STAs not established	• Applicable for treatment of all waste streams in the EAA
Managed Wetlands	• Capable of achieving lower effluent P concentrations than wetlands alone • Increased flexibility and reliability over wetlands due to process control • Less land area required than with wetlands alone	• Large amount of agricultural land must be taken out of production • Chemical treatment could impact effluent water chemistry • Higher O&M requirements than with wetlands alone	• Applicable for treatment of all waste streams in the EAA

Table 3 Summary of Treatment Technologies Considered in the Phase I Evaluation (continued)

Technology	Primary advantages	Primary disadvantages	Applicability to the EAA
Direct filtration	• Proven technology • Capable of achieving very low effluent P concentrations • Similar application of technology on stormwater runoff in Europe • Low land area requirements • Process control provides for a high degree of treatment performance reliability	• Chemical dosage may impact effluent water chemistry • O&M labor requirements • Requires processing and disposal of residual solids	• Applicable for treatment of all waste streams in the EAA
Barge treatment	• Capable of P removal during dry weather and low flow conditions	• Proprietary technology--treatment process information not available • No treatment units in operation at any scale • Very high O&M requirements	• Technology must be defined and field tested before applicability to the EAA can be considered further
Overland flow	• Natural treatment system • Proven technology, capable at removing phosphorus from wastewater treatment plant effluents • Harvesting of grass crop consistent with farm operations	• No advantages over wetlands for P removal capability, land area requirements, or capital cost • Unable to meet SWIM Plan P reduction goals as sole method of treatment • High O&M requirements	• Most applicable for polishing of effluents from point source treatment facilities to achieve greater P removals

Chemical Treatment. Chemical treatment for the removal of phosphorus involves the addition of chemicals such as calcium, aluminum, or iron salts to precipitate phosphorus and allow its removal through sedimentation or filtration. The typical chemical treatment process consists of chemical addition immediately followed by rapid mixing, coagulation, flocculation, sedimentation, and/or filtration.

For the EAA, it has been proposed that chemical treatment could be carried out at the farm scale in new or modified existing canals, and at larger scales in treatment modules also made up of canals. Residual solids would be dredged out as necessary and disposed of by land application. While chemical treatment is capable of achieving TP concentrations less than the 50 ppb TP goal in controlled environments, its capability to achieve very low effluent TP levels in agricultural canals has not been demonstrated. Field testing is needed to confirm the performance of this technology as it has been proposed for the EAA.

Limerock Sorption. Laboratory experiments conducted at Louisiana State University have indicated that phosphorus can be removed from water by contact with limerock ($CaCO_3$). As a treatment method for the EAA, it was assumed that the limerock would be obtained locally, crushed on-site, and placed into long channels for contact with the agricultural runoff. Sorptive capacity is highly dependent on the type of limerock available. None of the laboratory experiments conducted to date have simulated conditions that would be expected for large-scale implementation in the EAA. Therefore, the performance capability of this technology must be considered questionable until field tests in the EAA can be conducted.

Sedimentation in Limestone Borrows. Limestone has been excavated throughout South Florida for use as construction-grade limerock. The mining of this material has left numerous deep limestone borrow pits which are now lakes. Limited phosphorus removal can occur in these pits as the result of precipitation and adsorption. However, for this evaluation it was assumed that the limestone borrow pits would be preceded by chemical addition and would act as sedimentation basins. In this capacity, they would have the ability to enhance the performance of chemical treatment systems that otherwise would rely on sedimentation in ditches or canals. The applicability of this approach would be for treatment of farm scale or subbasin scale discharges that are located in close proximity to existing borrow areas.

Percolation Ponds. Percolation ponds remove particulate phosphorus by sedimentation and soluble phosphorus by adsorption and chemical precipitation/filtration in the soil profile. Flow through percolation ponds in the EAA would be horizontal through pond dikes towards perimeter canals, with a limestone caprock 5 to 10 feet below the ground surface to retard vertical percolation. The appropriate level of contact with the adsorptive soils is obtained by the construction of a levee between the percolation pond and the perimeter canal. To achieve very low effluent TP concentrations sufficient levee length and width must be provided. Because of the low adsorptive capacity of the muck soils in the EAA, the size of percolation ponds to treat agricultural drainage water is prohibitively large. Percolation ponds are most applicable for low volume, high strength waste streams.

Deep Well Injection. Deep well injection involves pumping wastewater into deep subsurface geologic zones where the wastewater can be stored for extended periods of time. The wastewaters are pumped down to the Oldsmare Limestone, or "boulder zone," located about 2,700 to 3,300 feet below land surface within the Lower Floridan Aquifer. Though not a treatment process, deep well injection has been proposed as an alternative technology for reducing phosphorus discharges from the EAA. This technology has been implemented for the disposal of effluent from all three of the municipal wastewater treatment plants in the EAA. However, it is very costly for large discharges and it is questionable whether permits could be obtained for widespread use of deep well injection for disposal of EAA runoff. This technology is clearly most applicable for reducing phosphorus discharges from low volume, high strength waste streams such as those found at sugar mills.

Aquifer Storage and Recovery. Aquifer storage and recovery (ASR) is based on the premise that water may be placed in a subsurface aquifer with favorable geologic and hydrogeologic conditions for storage and subsequent retrieval for beneficial use. At the basin and subbasin scale, ASR is being considered as a component of a regional water resource management plan to increase the quantity of water available for water supply. At the farm scale, growers are considering ASR as a means of reducing the volume of irrigation water pumped onto farms from District canals as well as the volume of drainage water pumped from farms into District canals.

A large-scale ASR demonstration project was performed in 1988 with stormwater runoff from the Lake Okeechobee basin. Water was injected into the Upper Floridan Aquifer located 1,300 to 1,700 feet below land surface. It was observed during the test that about 30 percent of the phosphorus present in the injected water was removed, presumably due to contact with the limestone strata. The ASR demonstration project required exemption from numerous FDER regulations for permit approval. It is doubtful that such exemptions could be obtained on a widespread basis in the EAA without substantial long-term testing of water quality impacts in the Floridan Aquifer. Therefore, the capability of ASR to provide significant reductions in phosphorus loads from the EAA in the short term must be considered limited.

Water Quality/Supply Diversion Plan. A Water Quality/Supply Diversion (WQ/SD) Plan was developed to address water quality problems in the Water Conservation Areas (WCAs) and Everglades National Park and to assist in solving water supply problems in the urban areas of Palm Beach, Broward, Dade, and Monroe Counties. Phosphorus loadings to the WCAs in runoff from the EAA would be reduced by diverting this flow to the coastal areas to recharge the surficial aquifer or to meet other water supply demands. Currently, water is released from the WCAs to the Lower East Coast. These releases would be curtailed to offset the reduced flows into the WCAs. Implementation of the WQ/SD Plan would require improvements and modifications to the Central and South Florida Flood Control Project facilities, as well as the construction of holding reservoirs to provide temporary storage of peak runoff volumes for later diversion. The WQ/SD Plan has not been defined in detail at the present time. It is not possible to estimate with any degree of certainty what the phosphorus reduction potential and capital cost of the WQ/SD Plan might be. The Plan needs to be defined before any further assessment of its potential for removing phosphorus from EAA discharges is made.

Algal Turf Scrubbers. Algal treatment has primarily been used for research and demonstration projects and for maintaining water quality in controlled aquatic environments. For application in the EAA, an experimental and proprietary algal turf scrubbing system has been designed and is being pilot tested on agricultural drainage water in the EAA. Water is introduced into long, narrow channels with a water depth of 8 to 12 inches called "flow-ways" which are lined with a textured geosynthetic membrane. Algae attach to the membrane. As the water passes through the flow-ways, phosphorus is taken up by the algae. Pilot plant data suggest that very low effluent phosphorus concentrations, on the order of 50 ppb or less, are achievable with the technology. However, biomass must be harvested periodically to maintain a high phosphorus removal efficiency. To date, no testing of procedures for harvesting, processing, and marketing/disposal of biomass has been accomplished. Overall, algal turf scrubbers appear to be a very promising technology, but must be field tested at full scale before they can be seriously considered for widespread application in the EAA.

<u>Nutrient Management System</u>. The nutrient management system (NMS) is a proprietary managed biological treatment system developed several years ago. It has been applied primarily at dairy farms for treatment of barn wastes and surface runoff, including two farms north of Lake Okeechobee. As applied for dairy wastes, the NMS is a sequence of physical, chemical, and biological treatment processes. Treatment units include (1) a solids separator; (2) a bioreactor, with optional chemical feed; (3) an ecoreactor; and (4) an optional georeactor, if necessary, for additional phosphorus removal. Depending on flow rates, waste characteristics, and effluent requirements, multiple units or treatment cells can be provided.

The NMS technology has been successful in reducing phosphorus levels in high strength dairy wastes by 95 percent or more. However, the technology has not been applied on wastewaters with very low phosphorus concentrations. It is not clear exactly how the technology would be applied on agricultural drainage water in the EAA. However, a pilot plant currently is being planned for construction in the EAA to allow testing of the technology on drainage from sugarcane land. The capability of the NMS technology to remove phosphorus from EAA drainage water will be better defined once data from this field testing is available. Without this pilot plant information, the NMS technology cannot be considered feasible for implementation in the EAA because of the time needed for process development.

<u>Ozone Treatment</u>. The Ecozone System is a proprietary treatment technology using ozone and other treatment processes for removing pollutants from wastewaters. It has been suggested that the Ecozone System might be used for the removal of phosphorus from EAA runoff. The technology involves treatment with ozone, ultraviolet light, activated carbon (if necessary), and proprietary blends of insoluble, inorganic catalytic agents to enhance the speed and effectiveness of the chemical reactions that take place. Due to its proprietary nature, no specific information is available on the treatment processes or the sequence in which they are applied. The Ecozone System is sold in 100,000-gpd modules. Therefore, thousands of them would be required to treat large volumes of agricultural drainage. This technology is not feasible for phosphorus removal in the EAA except perhaps for treatment of selected point source discharges.

<u>Sediment Dredging</u>. It is well known that there is considerable bed load sediment on the bottom of the District's canals. It is possible that if these existing sediments could be removed, there would be an immediate reduction in the phosphorus load leaving the EAA. Hydraulic dredging of the District canals could be accomplished in less than 1 year at a small fraction of the cost of other treatment technologies. Residual solids dredged from the canals would be disposed

of on agricultural land. About 14,000 acres of land would need to be taken out of production for a period of 1 year. However, the dredging operation would be a one-time activity.

Sediment dredging has the potential to be one of the most cost-effective treatment technologies available to the District for reducing phosphorus discharges from the EAA. However, before sediment dredging can be considered seriously, it is necessary that studies be undertaken to determine the impact of its implementation on the phosphorus load being discharged. Factors that should be evaluated in these studies include (1) the impact of sediment scour on TSS and TP levels in water discharged to the WCAs, (2) the impact on TP fractionation, and (3) the phosphorus content of the sediments themselves.

Wetlands. Constructed wetlands, in the form of four large basin scale STAs, are proposed in the current SWIM Plan for removal of phosphorus from EAA drainage water. A total of about 35,000 acres of agricultural land would need to be taken out of production to construct the STAs as currently proposed. The conceptual design criteria for the STAs that were presented by Burns & McDonnell in March 1992 served as the basis of evaluation for the wetlands treatment technology at the basin scale. These same criteria were also applied to evaluate wetlands treatment at the subbasin, farm, and point source scales of application in the EAA.

While the ability of the STAs to achieve the 50 ppb TP concentration required in the SWIM Plan on a consistent and reliable long-term basis has been questioned, the constructed wetlands treatment technology was used as the base case alternative for comparative evaluation purposes. Wetlands treatment is applicable at all scales in the EAA. Demonstration of TP removal at low concentrations, however, is a key factor. Data from the District's ENR Project would be beneficial, but this data will not be available for use in the alternative evaluation process. The transferability of TP removal data from WCA-2A to the STAs is questionable.

Managed Wetlands. The managed wetlands treatment technology incorporates the benefits of natural treatment in constructed wetlands with treatment processes that can enhance phosphorus removal performance. For this Phase I screening evaluation, it was assumed that chemical precipitation of phosphorus and overland flow, for solids filtration and flow distribution, would reduce influent TP levels to no more than 0.1 mg/l before entry into the STAs. In this way, the probability of the STAs' achieving the 50 ppb TP goal on a reliable basis is greatly increased. The capital cost of this technology would be greater than with STAs alone, unless land requirements could be reduced, and O&M requirements would also be greater. However, the TP removal performance of the treatment system would be significantly improved.

Direct Filtration. Direct filtration technology involves chemical precipitation and flocculation and removal of solids on granular media filters. No intermediate sedimentation step prior to filtration is accomplished and, as a result, the technology is only applicable for waste streams with suspended solids concentrations less than about 50 to 75 mg/l. Based on District data, suspended solids concentrations in drainage water from the EAA are in this range. Furthermore, lower chemical dosages are required because floc particles do not need to be nearly as large for effective filtration to occur than they do for effective sedimentation to occur.

The direct filtration technology has been successfully implemented for treatment of stormwater in Germany. Effluent TP levels as low as 5 ppb have been reported. Direct filtration has the potential to reduce TP levels in EAA discharges to 50 ppb, or less, with significantly less land requirements than the STAs. O&M labor requirements, however, would be greater than with the STAs. Direct filtration technology appears to be most applicable at the basin scale because of the significant economy of scale that can be achieved with construction of larger facilities. Direct filtration is also the most reliable of the treatment technologies considered in this Phase I evaluation.

Barge Treatment. This is a treatment system that would be constructed on shallow draft barges. The barges would be operated on the District canals during both wet and dry weather conditions. The treatment process is proprietary and little is known about the mechanism for TP removal. Laboratory experiments have reportedly shown TP removal levels as high as 99 percent. However, the treatment system has not been tested on water in the District's canals and there is no way to estimate TP removal performance without knowledge of the treatment processes being used. The concept of treating water on barges is novel. However, based on the limited information available regarding the treatment processes proposed, this technology is not applicable in the EAA.

Overland Flow. Overland flow is a natural treatment system in which wastewater is applied at the top of a vegetated slope, flows in a thin film over the soil surface, and is collected at the bottom for discharge or recirculation. Removal of suspended and dissolved constituents occurs by physical, chemical, and biological means with most of the removal occurring in the organic mat on the soil surface. The primary phosphorus removal mechanisms are sorption onto surface soils, precipitation as insoluble complexes of calcium, iron, and aluminum, and plant uptake. Harvesting of the grass crop removes phosphorus from the system. Overland flow systems have proven to be very effective in removing nutrients from wastewater treatment plant effluents where low-flow, high-strength waste streams require treatment. For EAA drainage water, however, overland flow does not appear to offer any advantages over the STAs in terms of TP removal capability or land area requirements.

INVESTIGATION RESULTS

Presented in Table 4 is a summary of key findings related to the phosphorus removal capability, implementation schedule, land area requirements, and capital cost of the 16 alternative treatment technologies considered in this Phase I screening evaluation. These factors will ultimately play a major role in decisions regarding which alternatives to implement as part of the SWIM Plan. Arraying the various technologies according to these key factors at this early planning stage is useful for detecting major differences between them.

The technologies with the highest phosphorus reduction capability are chemical treatment (with sedimentation in limestone borrow areas), percolation ponds, deep well injection, algal turf scrubbers, managed wetlands, and direct filtration, all capable of achieving 75 percent phosphorus removal on a long-term average basis. Of these, direct filtration is capable of achieving the lowest effluent phosphorus level, as low as 0.005 mg/l (5 ppb). The base case wetlands alternative (STAs) is capable of achieving between 50 and 75 percent phosphorus reduction on a long-term average basis.

Many of the treatment technologies with high phosphorus removal capabilities are also implementable by 1997. These include the chemical treatment, wetlands, managed wetlands, and direct filtration alternatives. Implementation of the percolation pond, deep well injection, and algal turf scrubber technologies throughout the EAA by 1997 is questionable.

Land area requirements favor the chemical treatment and direct filtration technologies over natural treatment technologies such as wetlands and managed wetlands. Our preliminary analysis indicates that four basin scale direct filtration treatment plants will require about 1 percent of the land area required to construct the four STAs as currently proposed in the District's SWIM Plan. The STAs, however, are expected to have one of the lowest capital costs of all the technologies, as well as lower O&M requirements. Trade-offs between phosphorus removal capability, land area requirements, and implementation cost will need to be carefully examined during the Phase II alternatives evaluation and the subsequent Plan Formulation stage of project development.

Table 4 Summary of Key Investigation Results

Treatment technology	Maximum P reduction capability,[a] percent	Imple-mentable by 1997	Land area required, acres				Capital cost,[b] million dollars			
			Basin	Subbasin	Farm	Point Source	Basin	Subbasin	Farm	Point Source
Chemical treatment	50 - 79	Yes	3,700	3,700	2,250	70	350	680	730	18
Limerock sorption	25	No	28,000	28,000	20,000	310	530	530	475	6
Limestone borrows	75	Yes	2,200	2,200	1,900	100	250	480	520	21
Percolation ponds	75	No	1,400,000	1,400,000	1,038,000	42,000	34,000	34,000	34,000	980
Deep well injection	75	No	1,100	2,100	3,100	130	670	730	860	35
Aquifer storage and recovery	25 - 50	No	1,100	2,100	3,100	130	260	300	340	14
Water Quality/Supply Diversion	25 - 50	Yes	N/A	--	--	--	N/A	--	--	--
Algal turf scrubbers	75	No	5,400	5,400	3,800	150	630	700	730	30
Nutrient management system	50 - 75	No	28,100	33,800	23,900	5,500	470	690	850	120
Ozone treatment	N/A	Yes	380	380	260	30	12,000	12,000	8,000	900
Sediment dredging	25	Yes	14,000[c]	--	--	--	34	--	--	--
Wetlands	50 - 75	Yes	32,000	32,000	27,000	3,600	330	360	410	39
Managed wetlands	75	Yes	35,000	35,000	29,000	3,900	400	500	750	58
Direct filtration	75	Yes	280	400	350	19	420	1,280	2,420	110
Barge treatment	N/A	No	260	55	--	--	220	220	--	--
Overland flow	50 - 75	Yes	48,000	48,000	38,000	1,100	620	680	640	24

Note: N/A = information not available; "--" = technology not evaluated at this scale.

[a] Brown and Caldwell's estimate of maximum P removal level achievable on a reliable basis.
[b] Capital costs in August 1992 dollars.
[c] Requires use of land for 1 year only.

PHASE I EVALUATION RATINGS

A summary of the Phase I evaluation ratings for the alternative treatment technologies is presented in Exhibit 1. The alternatives are arrayed according to how they scored at the basin scale of application in the EAA. The ratings in Exhibit 1 reflect the total scores given to each of the technologies out of a possible score of 160 points. The ratings provide an indication of how the various technologies were scored against the set of nine evaluation criteria as a whole. The ratings also provide an indication of how each technology scored in relation to the other technologies evaluated. Detailed evaluation rating sheets for all 16 technologies are presented in Chapter 3 of this report.

CONCLUSIONS AND RECOMMENDATIONS

Based on the Phase I evaluation ratings, the following conclusions are made:

1. At the basin scale of application, the three top rated treatment technologies are wetlands (STAs), managed wetlands, and direct filtration. No one technology has a clear advantage over the other two. All three technologies have excellent phosphorus removal capabilities, although there is some question about the ability of the STAs to reduce phosphorus levels by 75 percent on a consistent and reliable basis. The managed wetlands system, as developed for this evaluation, uses somewhat more land than the STAs. The direct filtration alternative uses significantly less land. The direct filtration alternative and the managed wetlands alternative both have similar capital costs to the STAs. Implementation schedule favors direct filtration, since less land needs to be purchased, construction time will be less, and start-up will be faster. However, conceptual design of the STAs has already been accomplished and the permitting process has already been initiated.

2. The three treatment technologies top rated at the basin scale are also top rated at the subbasin scale. The major differences are the increased cost and permitting requirements and the potentially longer implementation schedule associated with the larger number of treatment facilities.

3. At the individual farm scale, the three top rated treatment technologies are wetlands, managed wetlands, and chemical treatment. The wetlands and managed wetlands alternatives require that significant percentages of farm land be taken out of production, whereas chemical treatment can be accomplished in on-farm canals. Limestone borrow areas can be used as sedimentation basins to enhance phosphorus removal performance if they are located nearby. On-farm chemical treatment also offers the capability to enhance the phosphorus removal performance of water table management BMPs that include hydraulic improvements or storage of drainage water on-farm prior to discharge.

4. The top rated technologies for treatment of point source discharges are wetlands, managed wetlands, direct filtration, deep well injection, and percolation ponds. In addition, chemical treatment may be a viable option, particularly if limestone borrow areas are located nearby. This Phase I evaluation focused on discharges from sugar mills as the predominant point source of phosphorus in the EAA. Each mill has different wastewater characteristics in terms of flow and constituent concentrations, and different site characteristics in terms of soils, land area availability, and proximity to canals. In addition, there are numerous other point sources throughout the EAA which might not be as significant individually, with respect to phosphorus discharges, as the sugar mills, but could be significant when considered in an aggregate sense. These include municipal wastewater treatment plants, small package wastewater treatment plants, fertilizer plants, and vegetable packaging plants. Because of the wide range of waste stream characteristics associated with the various point sources in the EAA, any of the six technologies identified above could be appropriate for point source application depending on site-specific conditions and the level of treatment required.

5. Dredging of sediments from the bottom of the District's canals may be a cost-effective means of phosphorus removal. Although it can only achieve part of the phosphorus reduction goal, sediment dredging can be implemented quickly and at reduced cost compared with the other alternatives. It also requires no long-term utilization of land. If a meaningful reduction in phosphorus load can be projected as the result of water quality studies currently being considered by the District, sediment dredging may well be one of the more attractive technologies from the standpoint of dollars spent per pound of phosphorus removed.

6. Aquifer storage and recovery has the potential to play a significant role in the management of water resources in the region, particularly with respect to water supply. If used to reduce farm drainage discharges by recycling stormwater for use as irrigation water, it can also result in significant reductions in phosphorus load from the EAA. Current regulations and permitting procedures for ASR projects make its viability questionable as a short-term treatment technology for meeting the phosphorus reduction requirements of the SWIM Plan. However, should ongoing field testing of the technology result in modifications to regulatory procedures that facilitate its widespread implementation, ASR can serve as an effective means of reducing the size of other treatment facilities in the EAA.

7. Several technologies with high phosphorus removal capability would be prohibitively difficult to implement throughout the EAA. Examples of these technologies include percolation ponds, because of the large land area and construction requirements, and deep well injection, because of water resource utilization and permitting issues. Application of these technologies in the EAA can only be on a very limited basis.

8. Technologies still in the developmental stages must be field tested to demonstrate their capability to remove phosphorus from EAA runoff to very low levels. Until this is accomplished, their applicability in the EAA should not be considered further. These

technologies include limerock sorption, algal turf scrubbers, and the Nutrient Management System.

9. The Water Quality/Supply Diversion Plan has merit from the standpoint of regional water resources management. However, it is unclear how much phosphorus load can be reduced and at what cost. Components of the Plan have not been defined. This must be accomplished before a feasibility evaluation can be made.

10. Proprietary technologies that have been developed only conceptually in the laboratory, and for which no detailed treatment process information is currently available to the District, are not applicable for implementation in the EAA. These technologies include the ozone treatment and barge treatment alternatives.

Based on the results of the Phase I screening evaluation, it is recommended that the District move forward with the detailed evaluation of top rated technologies for each scale of application in the EAA. These are summarized in Table 5.

Table 5 Technologies Recommended for Detailed Evaluation

Scale of application			
Drainage basin	Subbasin	Individual farm	Point source
Wetlands Managed wetlands Direct filtration	Wetlands Managed wetlands Direct filtration	Wetlands Managed wetlands Chemical treatment[a]	Wetlands Managed wetlands Direct filtration Deep well injection Percolation ponds Chemical treatment[a]

[a] Chemical treatment could also involve use of limestone borrow areas for sedimentation, if appropriate.

During the Phase II evaluation, each technology should be applied to actual waste streams in the EAA so that differences between technologies can be better defined.

Exhibit 1 Summary of Phase I Evaluation Ratings

Technology	Scale of application/level of phosphorus reduction											
	Drainage basin			Subbasin			Individual farm			Point source		
	25	50	75	25	50	75	25	50	75	25	50	75
Managed wetlands	129	127	121	127	124	119	117	107	97	119	113	107
Wetlands	131	127	111	129	125	109	122	119	103	121	119	103
Direct filtration	118	116	112	114	111	107	104	98	91	118	115	112
Sediment dredging	118	--	--	--	--	--	--	--	--	--	--	--
Chemical treatment	104	97	85	104	97	84	107	101	90	108	104	97
Sedimentation in limestone borrows	101	95	89	101	95	87	103	98	91	108	104	100
Overland flow	100	92	83	99	91	82	100	92	83	106	102	96
Nutrient management system	94	87	77	92	85	75	86	79	70	99	93	87
Percolation ponds	88	80	72	88	80	72	90	84	78	117	110	100
Aquifer storage and recovery	73	--[a]	--	78	73	--	82	77	--	83	78	--
Algal turf scrubbers	77	70	63	76	70	63	85	79	72	85	80	73
Deep well injection	78	69	59	83	79	72	89	88	82	124	123	121
Limerock sorption	69	62	52	70	63	53	80	71	63	87	74	69
Water quality/supply diversion plan	78	53	--	--	--	--	--	--	--	--	--	--
Barge treatment	60	56	54	60	56	54	--	--	--	--	--	--
Ozone treatment	63	60	57	63	60	57	63	60	57	65	62	59

[a] "--" indicates technology not evaluated at this scale of application or level of phosphorus reduction.

CHAPTER 1

INTRODUCTION

CHAPTER 1

INTRODUCTION

This report documents work performed during the Phase I evaluation of alternative treatment technologies for reducing phosphorus discharges from the Everglades Agricultural Area (EAA). The report is in fulfillment of the work authorized under Amendment No. 2 to Contract C-3051 between the South Florida Water Management District (District) and Brown and Caldwell Consultants.

BACKGROUND

In March 1992, the District's Governing Board adopted the Everglades Surface Water Improvement and Management (SWIM) Plan consistent with a Settlement Agreement between the United States, the Florida Department of Environmental Regulation, and the District. The primary objective of the SWIM Plan is to reduce phosphorus discharges from the EAA while maintaining suitable hydroperiod in water conservation areas and the Everglades National Park. The strategy contained in the current SWIM Plan includes the following primary elements:

1. The construction and operation of four Stormwater Treatment Areas (STAs), large-scale constructed wetland treatment systems which will process storm runoff for the removal of nutrients.

2. The initiation of a regulatory program having as its goal the reduction of present total phosphorus loads discharged from the EAA by 25 percent. That regulatory program is to include the development and implementation of best management practices (BMPs) by property owners in the EAA.

3. The initiation and maintenance of a comprehensive, long-term multiagency research and monitoring program intended to:

    a. Numerically define applicable water quality standards.

    b. Assess current and continuing responses of the Everglades Protection Area to nutrient input levels.

In approving the SWIM Plan, the District's Governing Board committed to minimizing economic impacts on the area by continuing to consider alternatives that could satisfy the mandated performance requirements of the Settlement Agreement and to amend the SWIM Plan if necessary. In April 1992, the District hired Brown and Caldwell to assist in the evaluation of alternative treatment technologies for possible inclusion in the SWIM Plan in conjunction with the wetland systems currently proposed.

The first step in the alternatives evaluation process (Amendment No. 1) was the development of the methodology and criteria to be used in performing the evaluation. The results of this Amendment 1 work were submitted to the District in a July 1992 task report entitled Evaluation of Alternative Treatment Technologies--Evaluation Methods and Procedures. Evaluation of alternative treatment technologies is to be accomplished using a two-phase approach. The Phase I evaluation, which is the subject of this task report, is intended to provide an initial screening of the technologies. Those technologies passing the screening evaluation will be evaluated in detail in Phase II (Contract C-3051, Amendment 4) using site-specific data compiled by the District.

PURPOSE OF THE PHASE I EVALUATION

The purpose of the Phase I evaluation of alternative treatment technologies is to identify those technologies that have the greatest potential to become meaningful components of the District's SWIM Plan, based on information currently available, and to eliminate other technologies from further consideration at this time. Reducing the available technologies to those that have the most promise for application in the EAA at the present time will facilitate the more detailed Phase II evaluation, which will be based on site-specific flow and phosphorus data.

REPORT ORGANIZATION

This report is organized into four chapters. Following this introduction, the bases for performing the Phase I evaluations are described in Chapter 2. The evaluations of the alternative treatment technologies are discussed in Chapter 3. Conclusions resulting from the Phase I evaluations, including identification of those treatment technologies to be evaluated in detail in Phase II, are presented in Chapter 4. Detailed descriptions of the Phase I evaluation criteria and how they were applied in this investigation are presented in Appendix A.

CHAPTER 2

BASIS OF EVALUATION

CHAPTER 2

BASIS OF EVALUATION

This chapter presents the basis for performing the Phase I evaluation of alternative treatment technologies. A summary of the evaluation methodology is presented. The flows and phosphorus concentrations used in the evaluation are identified. The assumptions and procedures used in the sizing and costing of capital improvements required are also discussed.

EVALUATION METHODOLOGY

The methodology used in this investigation was developed in the Amendment 1 report entitled "Evaluation of Alternative Treatment Technologies--Evaluation Methods and Procedures," submitted previously to the South Florida Water Management District (District).[1] This report outlined a two-phase approach to the evaluation process: (1) a Phase I screening evaluation in which the various treatment technologies are rated against a set of general criteria at four scales of application and three levels of phosphorus reduction, and (2) a Phase II evaluation in which the top rated technologies at each scale of application are analyzed in more detail against an expanded set of evaluation criteria. The following paragraphs briefly summarize the methodology developed for the Phase I evaluation of alternative treatment technologies.

Basis for Phase I Evaluation Methodology

It is recognized that the various treatment technologies proposed for the EAA may not all be applicable at the basin scale as direct alternatives to the large stormwater treatment areas (STAs) currently proposed in the District's Surface Water Improvement and Management (SWIM) Plan. Some technologies may be much more economical or effective at a smaller scale or for treating discharges from point sources rather than drainage waters from agricultural fields. Consequently, the Phase I evaluation considers four different scales of technology application: (1) basin scale, accommodating flows from the S-5A, S-6, S-7 and S-8 basins; (2) subbasin scale, accommodating flows from groups of farms or designated drainage districts; (3) farm scale, accommodating flows from a single farm operation or a group of small farms; and (4) point source scale, focusing on discharges from sugar mills.

It is also recognized that the various treatment technologies proposed for the EAA may not all be capable on their own of achieving the long-term average goal of 50 parts per billion (ppb) total phosphorus (TP) in discharges to the water conservation areas (WCAs). Some technologies may be efficient at achieving a portion of the mandated reduction in phosphorus loading and can be used effectively in combination with other technologies to achieve the 50 ppb goal. Such technologies should not be eliminated from further consideration solely on the basis of not being able to reduce average phosphorus concentrations to 50 ppb on their own. Consequently, the Phase I evaluation considers three levels of phosphorus reduction capability: 25 percent, 50 percent, and

75 percent, all based on expected TP concentrations following implementation of on-farm best management practices (BMPs). The 75 percent reduction capability is intended to indicate that a technology can achieve the 50 ppb TP goal.

In evaluating the alternative technologies at the different scales of application and different levels of phosphorus reduction, it is important that consistency with the conceptual design of the constructed wetlands be maintained if this technology is to be used as the base case alternative for comparing other technologies. Therefore, assumptions regarding flows, phosphorus concentrations, and sizing and costing of treatment facilities in this Phase I evaluation are consistent with those used in the conceptual design of the STAs and farm treatment areas (FTAs).[2,3]

Phase I Evaluation Criteria

A set of nine criteria was established for use in the Phase I evaluation of alternative treatment technologies. These criteria are presented in Table 2-1. The criteria were selected because they represent a broad cross-section of considerations which must be addressed in the formulation of a phosphorus reduction program for the EAA and because they can be applied generally to the alternative technologies during the screening process without site-specific information on how the technologies are to be implemented. Descriptions of the nine criteria and how they are used in the Phase I evaluation of alternative treatment technologies are presented in Appendix A.

Table 2-1 Phase I Evaluation Criteria

Criterion	Criterion weighting
Phosphorus removal capability	3
Implementation schedule	2
Hydroperiod impact	2
Operational impact on C&SF project	2
Permitting requirements	2
Previous application of technology	2
Capital cost	1
O&M requirements	1
Economic impacts	1

Scoring System

The results of this Phase I evaluation will be used to determine whether an alternative technology should receive further evaluation and, if so, at what scale of application. This will require that comparisons be made between technologies on the basis of the evaluation criteria identified above. These criteria are not all equally important to the initial screening of technologies. A key element in the evaluation methodology, therefore, is the approach used to incorporate the relative importance of an individual criterion into the screening process.

For this Phase I investigation, a numerical scoring system is used to facilitate the comparison of technologies against the common set of evaluation criteria. The scoring system has two components: technology rating and criterion weighting. Technology ratings are used to numerically compare alternatives according to a single criteria. Criterion weights are used to compare the importance of one criterion in relation to other criteria. Multiplying the technology rating for a criterion by the weight of the criterion yields the score for that technology against that criterion. Addition of the scores for all criteria yields the total score for a technology.

Technology Rating. The Phase I evaluation criteria are designed to be used in a qualitative sense to judge the capability of a technology to meet the objectives of the SWIM Plan, based on the data and information that is currently available. The description of each criterion includes a range of conditions and characteristics, both positive and negative, and a proposed rating to be assigned accordingly. The ratings range from "10" for the most positive or favorable condition to "1" for the least positive or favorable condition. The ranges of conditions and proposed ratings are included with the descriptions of the individual Phase I evaluation criteria in Appendix A.

Criteria Weighting. As noted above, assigning weights to individual evaluation criteria is a way to reflect the importance of one criterion in relation to the others. An individual criterion is assigned a weighting factor ranging from 1 to 3 reflecting its relative importance in satisfying the goals and objectives of the SWIM Plan. Criteria with a weighting factor of 3 are critical to satisfying the objectives of the SWIM Plan. Criteria with a weighting factor of 1 do not have direct impact on the objectives of the SWIM Plan and, therefore, are not as important to the process of screening alternative technologies. The weighting factors for each criterion are presented in Table 2-1. Phosphorus removal capability is the most important criterion in the screening process and is assigned a weighting factor of 3. All other criteria have lower weighting factors as indicated in the table. Cost-related criteria were assigned a low weighting factor because (1) it was not intended that technologies be eliminated from further consideration on the basis of cost, and (2) the planning level cost estimates prepared for this Phase I screening evaluation were not considered accurate enough to warrant a higher weighting factor.

Analysis of Technology Ratings

The total scores for the various technologies at each of the four scales of application (basin, subbasin, farm, point source) and phosphorus removal levels (25, 50, and 75 percent) were compiled and a comparative evaluation of the technology ratings was made. For each scale of application, the several technologies with the highest ratings have been recommended for further evaluation in Phase II.

DEVELOPMENT OF FLOWS AND PHOSPHORUS LOADINGS

An important element of the Phase I evaluation of alternative treatment technologies is the development of flows and phosphorus loadings that treatment units must accommodate. Because of the lack of a comprehensive data base characterizing the quantity and quality of runoff from different portions of the EAA and discharges from point sources in the EAA, it is not possible to develop detailed design flows and phosphorus loadings. Ongoing work by the District and its consultants will provide the data needed for this to be accomplished in later phases of technology evaluation. However, for this Phase I evaluation, it is necessary to rely on the aggregate data collected by the District at the S-5A, S-6, S-7, and S-8 pumping stations for the period 1979 through 1988. This data was used for the conceptual design of the STAs.[2]

Presented below is a description of how the four scales of technology application are defined. Also presented are the flows and TP concentrations used in the Phase I evaluation for each scale of application, based on data from the 10-year historical period of record.

Scales of Technology Application

As indicated previously, the Phase I evaluation of alternative treatment technologies is carried out at four different scales of application: basin, subbasin, farm, and point source. Each of these scales of application is briefly defined below.

Basin Scale. Basin scale refers to the four large drainage basins tributary to the S-5A, S-6, S-7, and S-8 pumping stations. The STAs, currently proposed in the District's SWIM Plan, have been conceptually designed at the basin scale. In this Phase I evaluation, a typical basin is characterized as the average of the four basins in the EAA.

Subbasin Scale. Subbasin scale refers to a group of farms or a drainage district within a basin. For the purpose of this Phase I evaluation, it is assumed that there are ten typical subbasins within a typical basin.

Farm Scale. Farm scale refers to a single farm or group of small farms discharging directly to primary canals in the EAA. It is estimated that there are 250 or more individual farm discharges in the EAA. However, according to District records, there are 173 permitted discharges, some of which involve multiple discharge points.[3] For this Phase I evaluation, it is assumed that there are 173 typical farm scale treatment facilities required in the EAA, or an average of about 43 typical farms per basin.

Point Source Scale. Point source scale refers to any point source discharge of municipal or industrial wastewater within the EAA. This includes municipal wastewater treatment plants as well as urban runoff that is collected and discharged at a single point. The Belle Glade and South Bay municipal wastewater treatment plants dispose of treated effluent by deep well injection, but there are numerous other small package plants discharging treated effluent to surface and groundwater, and presumably contributing to the phosphorus load discharged from the EAA. Discharges to Lake

Okeechobee and the District's primary canals from urban drainage districts around the lake also contribute to the phosphorus load. For this Phase I evaluation of phosphorus removal technologies, however, the focus of the point source scale is on the seven sugar mills in the EAA that have the potential to discharge significant quantities of phosphorus into the groundwater, and eventually, into the primary canal system. There are also several vegetable packing plants in the EAA that could be considered, but in terms of contribution to phosphorus load, they are considered less significant than the sugar mills.

<u>Quantity and Variability of Flows</u>

Table 2-2 summarizes the flow parameters used in the Phase I evaluation of treatment technologies for each of the four scales of application. The following paragraphs summarize how the various flows were developed.

Table 2-2 Flow Parameters for Phase I Evaluation of Alternative Treatment Technologies

Flow parameters	Scale of application			
	Basin	Subbasin	Farm	Point source
Average annual flow, mgd	183	18	3	10
Maximum month flow volume, million gallons	22,300	2,230	390	450
Maximum month flow, mgd	743	74	13	15
Peak flow, mgd	2,330	233	33	20

<u>Basin Scale</u>. Average annual flow for the basin scale was derived by averaging the average annual flows for the four individual basins that are presented in the STA conceptual design report.[2] These flows assume a 20 percent reduction in future flow rates as a result of on-farm BMPs. Peak flow per basin represents the average capacity of the four primary pumping stations that deliver water to the WCAs. Conceptual design of the STAs assumes that all water delivered by these pumping stations will pass through the STAs and that none will be bypassed directly.

The maximum month flow volume was derived by averaging the highest monthly volume of flow from each of the four basins over the 10-year period of record. The average day flow during the maximum month, a typical design parameter for many wastewater treatment processes, was computed by dividing the maximum month flow volume by a factor of 30.

As evidenced by the figures in Table 2-2, flow rates at the primary pumping stations have a high degree of variability. Peak flow rates in excess of 12 times average annual flow are extremely high for the large land areas involved, but not unreasonable given the nature of farming operations within the EAA. Pumping events at the District's four primary pumping stations can last for a month or more with major rainfalls that are widespread throughout the EAA. However, no trends between rainfall and duration of pumping have been reported for any of the basins. During the wet season from June through October, the S-5A and S-6 pumping stations were operational an average of 37 and 33 percent of the days, respectively, over the 10-year period of record.

Subbasin Scale. Subbasin flows were derived by assuming ten equal hydrologic drainage units in each basin for a total of 40 in the EAA. Flow parameters for the typical, or average, basin were simply divided by a factor of 10 to arrive at flow parameters for the typical subbasin.

Farm Scale. Farm scale flow factors were based on the average annual runoff totals for four individual basins as presented in the District's conceptual design report for the FTAs.[3] These runoff totals differ from those presented for the four primary pumping stations in the STA conceptual design report in that they do not include releases from Lake Okeechobee. The average annual runoff from the four basins was reduced by 20 percent, to account for BMPs, and then divided by a factor of 173 to arrive at an average annual flow at the typical farm scale in the EAA.

Maximum month and peak flows at the farm scale were developed by applying the same factors to average annual flow as were applied at the basin and subbasin scales. While this method allows for sizing of treatment units at the farm scale to be accomplished in a manner consistent with the other scales, it does not account for cycling of farm pumps during the day or during a long pumping period. When all of the farm pumps are on, the peak flow may be considerably higher than that reflected in Table 2-2. This additional variability in farm scale flow rates cannot be quantified with the data available, but can be factored into the evaluation of technologies on a qualitative basis.

Point Source Scale. Review of FDER operational permits for sugar mills in the EAA indicate that permitted flows range from about 0.4 to about 70 million gallons per day (mgd). In some cases, the permit covers an individual waste stream within the mill, while in other cases the permit covers more than one waste stream. Discharges from mills typically include floor drainage from washdown operations, cooling water and wastewater from boiler operation, overflows and blowdown from scrubber operations, and mud slurries containing fly ash and residual solids from processing of cane. Most mills combine their process wastewater streams and discharge them to percolation ponds or other treatment facilities. These facilities are not typically permitted for direct surface water discharge.

Because there are no detailed effluent discharge flow records readily available, it is not clear how much of the permitted flow might actually require treatment for phosphorus removal. In this analysis, a maximum month process wastewater flow of 15 mgd was assumed for a typical sugar mill in the EAA. There are seven sugar mills in the EAA. Some probably generate maximum month flows in excess of 15 mgd and some probably generate much smaller flows. The 15 mgd is assumed to be representative of a maximum month process wastewater discharge from a typical, or average, mill in the EAA only for the purposes of this Phase I evaluation of alternative treatment technologies.

There is no data readily available to suggest what the average annual and peak process water flow rates from a typical mill might be. Mills usually operate only 5 to 6 months per year. Consequently, average annual or average day flow is of little value except possibly for estimation of annual flow volume and constituent loading. During the harvesting season, the mills are operational 24 hours per day, 7 days per week. Therefore, peak flows would not be expected to be significantly higher than the average day flow during the maximum month. For this evaluation, average annual flow was assumed to be 67 percent of maximum month flow. Peak flow rates were assumed to be 200 percent of average annual flow rates.

Phosphorus Concentrations

The primary sources of phosphorus data for drainage waters from the EAA are periodic grab samples taken by the District at the S-5A, S-6, S-7, and S-8 pumping stations. As reported in Burns & McDonnell's conceptual design report for the STAs,[2] the average TP concentration ranges from a low of about 0.1 milligrams per liter (mg/l) in Basin S-7 to a high of about 0.2 mg/l in Basin S-5A. The TP concentrations in the agricultural runoff from these basins would be expected to be slightly higher than these figures because the data from the pumping stations include the effects of releases from Lake Okeechobee which are reported to contain from about 0.06 to 0.12 mg/l TP.[2]

The phosphorus concentrations used in this Phase I evaluation of alternative treatment technologies are summarized in Table 2-3. A TP concentration of 0.15 mg/l was derived for the basin and subbasin scales as the flow weighted average for the four basins in the EAA. This figure is consistent with the conceptual design of the STAs and FTAs and assumes a 25 percent reduction in TP over historical levels resulting from future implementation of on-farm BMPs. While the TP concentration in agricultural drainage from individual farms might be expected to be slightly higher, there is no data to support what an average concentration across the EAA might be. Therefore, a TP concentration of 0.15 mg/l was also assumed for agricultural drainage water at the farm scale.

Table 2-3 Phosphorus Concentrations for Phase I Evaluation of Alternative Treatment Technologies

Parameters	Scale of application			
	Basin	Subbasin	Farm	Point source
TP concentration, mg/l	0.15	0.15	0.15	1.0
Soluble fraction, percent	75	75	75	100
Insoluble fraction, percent	25	25	25	0

There are no detailed studies to support a particular split between the soluble and insoluble fractions of TP being discharged at the four primary pumping stations. Analyses performed by the District and the Everglades National Park suggest that the TP may be as much as 75 percent soluble while analyses performed by the Florida Sugar Cane League indicate that as much as 50 percent may be insoluble. To be conservative in this analysis, it is assumed that 75 percent of the TP load is soluble and 25 percent is insoluble. Ongoing data collection should allow this assumption to be refined in future evaluations.

Review of monthly monitoring reports from several of the sugar mills in the EAA indicates that effluent TP concentrations vary tremendously, from less than 0.1 mg/l to more than 5 mg/l. Most mills have installed percolation ponds or other facilities to treat process water prior to its discharge. For the purposes of this evaluation, it is assumed that the typical pretreated discharge from a mill contains about 1 mg/l TP and that it is all in the soluble orthophosphate form as might be expected in the effluent from percolation ponds or settling basins. TP concentrations in the discharges from some mills may be considerably lower than 1 mg/l. Overall, however, this concentration is assumed to be representative of mills in the EAA in that it indicates an effluent TP concentration considerably higher than that typically found in EAA drainage water.

It should be noted that the flows in Table 2-2 and the phosphorus concentrations in Table 2-3 were developed independently of each other. Consequently, mass loadings of TP for point and nonpoint source discharges do not necessarily sum to the mass loadings reported elsewhere for individual basins in the EAA or the EAA as a whole. The figures in Tables 2-2 and 2-3 are presented only as being representative of the individual scales of application for this Phase I evaluation of treatment technologies.

SIZING OF TREATMENT FACILITIES

As indicated previously in the discussion of evaluation methodology, the sizing criteria for treatment units in this Phase I evaluation of technologies is intended to be as consistent as possible with the conceptual design of the STAs and FTAs. If the constructed wetland technology proposed for the STAs and FTAs is to be used as the base case for comparison purposes, then treatment facilities required to implement alternative technologies must be sized to accommodate the same flows and phosphorus loadings.

Bypassing and Flow Equalization

One of the fundamental issues related to treatment facility sizing involves bypassing of flow during high flow periods. The current conceptual design of the STAs assumes that all flows from the S-5A, S-6, S-7, and S-8 pumping stations will pass through the STAs and that no bypassing will occur. Sizing of the STAs and the smaller scale FTAs is based on annual phosphorus load. However, the hydraulic capacity of the treatment units is sufficient to accommodate peak flows without bypassing. Sizing of natural treatment facilities such as constructed wetlands and overland flow systems is accomplished similarly in this Phase I evaluation.

Bypassing of flow becomes more of an issue when considering physical, chemical, and biological treatment technologies that are engineered to achieve a stated level of performance at a specified flow rate. Sizing of treatment units, such as chemical feed systems, sedimentation basins, and bioreactors to accommodate peak flow rates would result in construction of large capital improvements that would be used very infrequently. Normally, the approach that is taken in such cases is to provide flow equalization storage and balance the size of flow equalization and treatment facilities to arrive at a least cost solution. In this case, however, the maximum month flow volumes and the peak flow rates from the EAA are very large and the land area required for flow equalization would be excessive. An October 1991 draft report by Burns & McDonnell, related to the conceptual design of the STAs, concluded that flow equalization was not a feasible approach to sizing of the STAs.[4]

Given that flow equalization at a large scale is probably not viable in the EAA, it is reasonable that engineered treatment systems be sized to allow for limited bypassing. The objective of the SWIM Plan is to achieve a long-term average of 50 ppb TP in discharges to the WCAs. Therefore, if TP concentrations can be reduced to below 50 ppb during low to moderate flows, then some limited bypassing can occur during high flow periods without impacting the long-term goal.

Design Capacity of Treatment Facilities

Sizing of treatment units for natural treatment technologies and the other engineered treatment technologies was accomplished somewhat differently because of the difference in how bypassing was considered. Natural treatment systems were sized according to average annual phosphorus load and standard hydraulic loading criteria while the other engineered technologies were sized on the basis of phosphorus removal capability and a detailed analysis of daily flows discharged from the EAA.

Natural Treatment Technologies. Natural treatment technologies, such as wetlands and overland flow systems, were sized to accommodate all flows, including peaks, without bypass. Wetland treatment units were sized on the basis of average annual TP loading rate and a TP settling rate of 8 meters per year (m/yr) as discussed in the STA conceptual design report.[2] A minimum detention time of 2 days was provided at peak flow. Overland flow treatment units were sized according to standard hydraulic application rates appropriate for the EAA. Peak flows were allowed to pass over the treatment slopes, but were not allowed to exceed double the flow depth at design capacity.

Other Technologies. An analysis of the daily flows recorded at the District's four primary pumping stations over the 10-year period from 1979 to 1988 was conducted to determine the required design capacity of treatment units for the other technologies. Using the flow weighted average influent TP concentration of 0.15 mg/l and the recorded daily flows, adjusted to account for a 20 percent reduction in EAA runoff resulting from implementation of BMPs, the average annual influent TP load per basin was computed. This totalled about 83,700 pounds, or about 42 tons, of TP per basin per year over the 10-year period of record.

For a given effluent TP concentration and design flow capacity, the pounds of phosphorus removed can be calculated using the difference between influent and effluent TP concentration and the quantity of flow treated. In this analysis, all recorded flows up to and including the design capacity of the treatment units were assumed to be treated. Flows in excess of design capacity were assumed to be bypassed. Only nonzero, positive flows were considered in the analysis.

TP removal percentages were computed over a range of effluent TP concentrations and treatment unit design capacities. The results of the analysis are illustrated on Figure 2-1 in the form of a series of curves. As effluent TP concentration decreases, the design capacity of treatment units also decreases to achieve the same TP removal percentage. Consequently, treatment units for technologies that have the capability to achieve very low effluent TP concentrations can be sized to treat less flow and bypass more flow than treatment units for technologies that cannot achieve as low an effluent TP concentration.

As an example, consider a treatment technology which is capable of achieving an effluent TP concentration of 0.02 mg/l and which is being evaluated at the basin scale. Based on the 10-year historical period of record, the required design capacity of the treatment units would be about 900 mgd to achieve a 75 percent reduction in TP on an average annual mass basis. All flows below 900 mgd would be treated to an average effluent TP concentration of 0.02 mg/l (87 percent reduction) and all flows in excess of 900 mgd could be bypassed without treatment. Similarly, to achieve average annual TP reductions of 50 and 25 percent using the same technology, design capacities could be reduced to 400 mgd and 200 mgd, respectively.

The above example considered application of a technology at the basin scale. At the subbasin scale, the design capacity of treatment units for 75, 50, and 25 percent TP reduction would be 90, 40, and 20 mgd, respectively, based on the assumption that there are 10 equal subbasins per average basin. Design flow capacities for treatment units at the farm scale can be derived by multiplying the design capacities at the basin scale by the ratio of average annual flow at the farm scale to average annual flow at the basin scale. In the above example, farm scale design capacities would be 15, 6, and 3 mgd, respectively.

It should also be noted that some technologies may not be capable of an effluent TP concentration low enough to achieve the 75 percent removal level as discussed in the above example. As shown on Figure 2-1, an effluent TP concentration of less than 0.04 mg/l is required to achieve 75 percent removal on a mass basis. Treatment units for technologies that cannot achieve an effluent TP concentration less than 0.04 mg/l were sized to accommodate peak flows at all scales of application for the 75 percent removal level.

For point source discharges, the relationships presented on Figure 2-1 do not apply. In this analysis, it was assumed that treatment units for point source discharges would be sized to accommodate the average day flow during the maximum month, provided that the technology is capable of achieving an effluent TP concentration of 0.05 mg/l or less. If not, the treatment units were sized to treat the peak flow.

<u>Downsizing of Treatment Units for Reduced Phosphorus Removal</u>

Downsizing of treatment units was allowed for certain treatment technologies when they were evaluated at the 50 and 25 percent phosphorus reduction levels. For downsizing of treatment units to be allowed, it was necessary that the treatment technology have a high rating for phosphorus removal capability. For example, a technology with a phosphorus removal rating of 8 or higher at

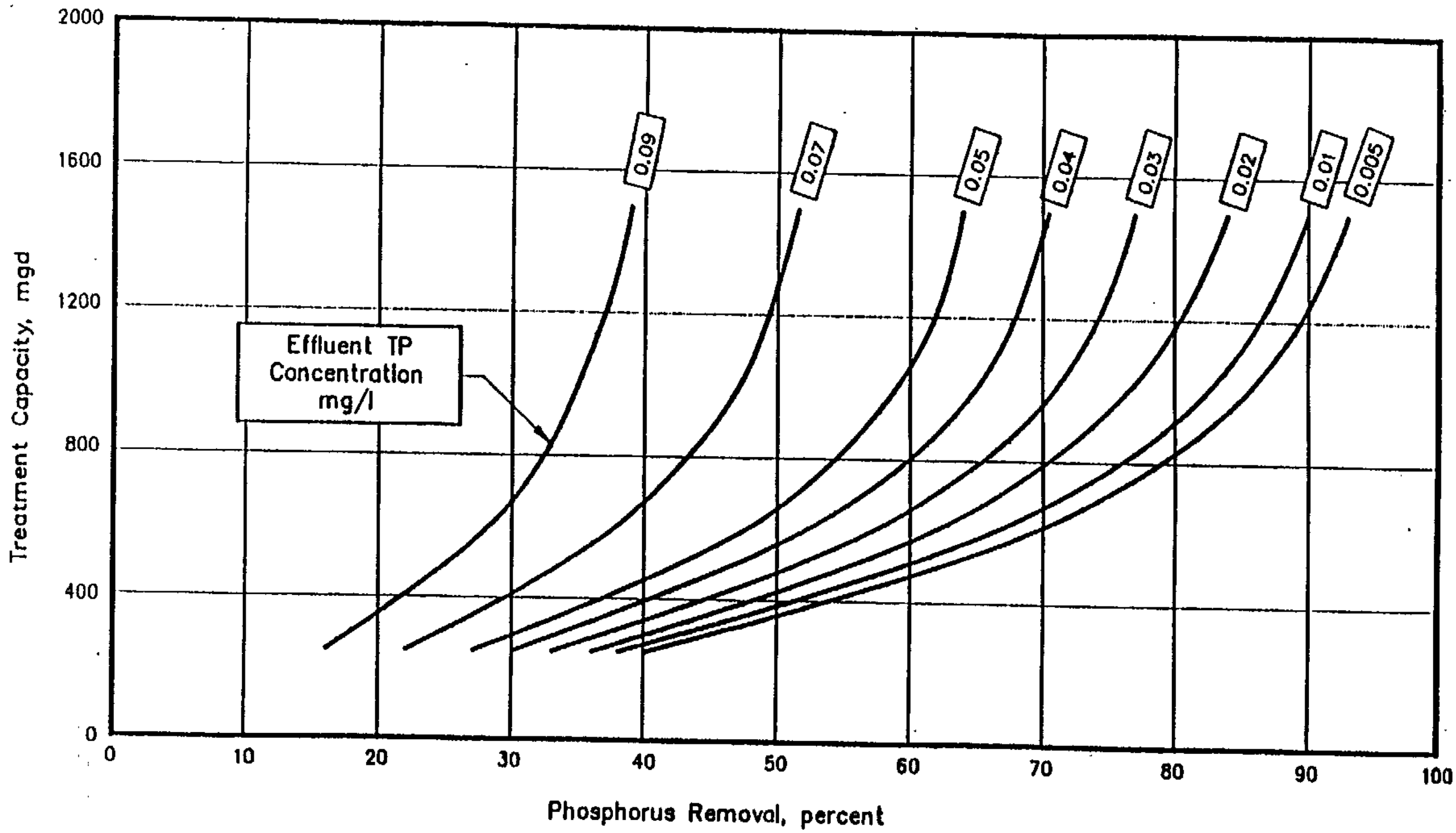

Figure 2-1
Relationship of Treatment Capacity and Effluent Phosphorus Concentration to Reduction in Phosphorus Load from the Everglades Agricultural Area

the 75 percent removal level could be downsized at the 50 and 25 percent removal levels if the smaller treatment units did not reduce the technology's phosphorus removal rating at those lower removal levels. In contrast, a technology receiving a phosphorus removal rating of 7 or less at the 75 percent removal level could not be downsized at 50 percent, but could be downsized at 25 percent if its phosphorus removal rating improved at the 50 percent removal level. To allow for downsizing of treatment units, it was assumed that design flow capacity could be reduced, according to the relationships illustrated on Figure 2-1, and additional flow could be bypassed as necessary to achieve the desired level of phosphorus reduction.

For some technologies, particularly those that are proprietary in nature, phosphorus removal performance is questionable because operating data are not available to support performance in applications similar to the EAA. In most of these cases, lower than average ratings for phosphorus removal capability were assigned because of the uncertainty involved. According to the guideline described above, treatment units for these technologies could not be downsized at the lower phosphorus removal levels. However, it was concluded that this would not provide for a fair evaluation of the technologies and, consequently, certain proprietary technologies were allowed to be conservatively downsized at the lower phosphorus removal levels even though their ratings for phosphorus removal capability are based on undocumented performance.

BASIS OF COST ESTIMATES

Planning level capital cost estimates were prepared as part of this Phase I evaluation to allow a general comparison of initial implementation costs between alternative treatment technologies and the wetlands treatment technology (STAs) currently contained in the District's SWIM Plan as the base case. With the exception of the STAs, the cost figures presented in this report are not based on site-specific application of technologies. This will be accomplished in the more detailed Phase II evaluation of treatment alternatives. Care has been taken throughout the cost estimating process to apply consistent judgment and assumptions, and as a result, the estimates prepared reflect differences between alternatives, relative to one another. However, because many of the technologies being considered in this Phase I evaluation are only concepts at this stage and have not been fully defined, the capital cost estimates presented herein can be expected to have an accuracy no greater than plus or minus 50 percent.

Capital cost estimates for treatment facilities are based on (1) information available from previous studies and reports; (2) information supplied by vendors and equipment suppliers associated with the treatment technologies being proposed; (3) information generally available in the literature; and (4) information available from previous projects completed by members of the Brown and Caldwell project team which involved similar construction activities. Capital cost estimates reflect land cost, construction cost, and cost allocations for planning, permitting, and design. Cost estimates provided by others have been checked for reasonableness by Brown and Caldwell to the extent possible. Where it was not possible for Brown and Caldwell to verify the reasonableness of a cost estimate, as in the case of proprietary equipment, that fact is noted in the evaluation of the technology involved.

Base construction cost estimates were prepared using the best available information from the sources cited above. Additional cost allocations were made as follows:

1. Site development costs (roads, administrative buildings, security, etc.), 2 to 5 percent.
2. Utilities (electrical, water, wastewater, etc.), 1 to 5 percent.
3. Process electrical and instrumentation, 2 to 10 percent.
4. Construction contingencies, 20 percent.

All construction cost estimates were adjusted to August 1992 dollars using an Engineering News Record Construction Cost Index of 5032. Land costs were assumed to average $2,750 per acre across the EAA. Engineering, legal and administrative costs were estimated at 15 percent of total construction cost, plus contingencies, but exclusive of land costs.

REFERENCES

1. Brown and Caldwell, Everglades Protection Project, Evaluation of Alternative Treatment Technologies, Amendment 1 Report--Evaluation Methods and Procedures, prepared for the South Florida Water Management District, August 1992.

2. Burns & McDonnell, Everglades Protection Project, Conceptual Design of the Stormwater Treatment Areas, report prepared for the South Florida Water Management District, January 1992.

3. South Florida Water Management District, Everglades Protection Project, Farm Stormwater Treatment Area Alternative, February 1992.

4. Burns & McDonnell, Everglades Protection Project, Feasibility Study--Stormwater Treatment Area No. 1, and Conceptual Design--Stormwater Treatment Areas STA-2, STA-3 and STA-4, draft reports prepared for the South Florida Water Management District, October 1991.

CHAPTER 3

EVALUATION OF TECHNOLOGIES

CHAPTER 3

EVALUATION OF TECHNOLOGIES

Presented in this chapter are the Phase I evaluations of the 16 alternative treatment technologies being considered for reducing phosphorus discharges from the Everglades Agricultural Area (EAA). The evaluations were carried out in accordance with the methodology described in Chapter 2. Conclusions drawn from the evaluation results are presented in Chapter 4.

The 16 alternative treatment technologies investigated in this Phase I evaluation are as follows:

1. Chemical treatment
2. Limerock sorption
3. Sedimentation in limestone borrows
4. Percolation ponds
5. Deep well injection
6. Aquifer storage and recovery
7. Water quality/supply diversion plan
8. Algal turf scrubbers
9. Nutrient management system
10. Ozone treatment
11. Sediment dredging
12. Wetlands
13. Managed wetlands
14. Direct filtration
15. Barge treatment
16. Overland flow

Evaluations for each of these 16 technologies are contained in separate sections of this chapter. Each evaluation section includes (1) a brief description of the technology being evaluated; (2) identification of assumptions, guidelines, loading rates, cost estimates, etc. used as the basis of the evaluation; (3) presentation of the evaluation results using the numerical scoring system described in Chapter 2; and (4) a discussion of the evaluation results summarizing the primary advantages and disadvantages of the treatment technology that led to the ratings it received.

It should be emphasized that the evaluation ratings presented in this chapter are intended to reflect the applicability of a technology against the various evaluation criteria in an aggregate sense over the entire EAA. This is particularly important at the smaller scales of application where many individual projects would have to be implemented to achieve the same results as a fewer number of larger projects.

CHEMICAL TREATMENT

Chemical treatment involving precipitation followed by solids separation has been used to remove phosphorus from water for many years.[1] Treatment steps may include rapid mix, coagulation, flocculation, sedimentation, and/or filtration. The technology evaluated in this section involves the application of precipitation, coagulation, flocculation, and sedimentation processes in new and modified existing canal sections in the EAA. This approach to application of the technology differs from the direct filtration approach, discussed later in this chapter, which relies on mechanical treatment equipment.

Overview of Technology

Chemical treatment using precipitation, coagulation, flocculation, and sedimentation has the potential to reduce total phosphorus (TP) concentrations in EAA water to less than 50 ppb. U.S. Sugar Corporation's water treatment facility at Clewiston reduces total phosphorus from 180 ppb to less than 50 ppb using a lime coagulation/settling process.[2] Precipitation, coagulation, and sedimentation also have been successfully applied in Holland to reduce phosphorus concentrations to very low levels.[3] Recently, successful application of chemical treatment technology has been achieved in Orlando, Florida using alum to remove phosphorus from urban stormwater runoff.

The proposed configuration for this treatment technology would utilize new and modified existing canal sections for rapid mixing, coagulation, and sedimentation.[2] Energy for both rapid mixing and coagulation would be supplied by in-stream mixers, which are not intended to impact existing hydraulics in the canals. Sedimentation traps would be excavated in the modified canals to retain settled solids. Solids would be pumped or dredged out of the canals, as necessary, and land applied. On larger scale projects, sludge lagoons would probably be required to concentrate solids prior to land application. Disposal of residual solids could be on agricultural fields or on land dedicated for that purpose.

The chemical treatment technology has been tested at the bench scale on EAA drainage water using various precipitants and coagulants by Dr. David Anderson of the University of Florida's Institute of Food and Agricultural Sciences (IFAS).[2] Test results indicate that TP concentrations can be reduced to less than 50 ppb using ferric salts combined with other chemicals. Aluminum salts could also be used, but concern over their ability to be land applied has reduced their attractiveness. Lime treatment is not favored currently because of the large chemical dosage required and the quantity of lime sludge that would be generated.

Dr. Anderson is in the process of developing a program for field-scale testing of the technology in the EAA. Based on the results of the bench-scale tests and experience from other operating plants, the process train proposed for treating EAA drainage water is precipitation of phosphorus by ferric salts, flocculation with the aid of a polymer, and solids separation by gravity sedimentation.[2] The field testing project is still in the planning stage and continuous-flow test data are not yet available.

Basis of Evaluation

The treatment system is proposed to be constructed in treatment modules, each with a capacity of 180 mgd. A typical treatment module, reflecting the proposed configuration, length, and depth of canals, is illustrated on Figure 3-1. A single treatment module, or portion of a treatment module, would be constructed at the farm and point source scales using existing canals to the extent possible. Existing canals would need to be widened and deepened to serve effectively as treatment units. At the subbasin and basin scales, multiple treatment modules would be constructed. A possible configuration for a basin scale treatment facility upstream of the S-150 pumping station is illustrated on Figure 3-2.

Chemical dosage rates were assumed to be 60 mg/l $Fe_2(SO_4)_3$ for precipitation, 0.35 mg/l polymer for coagulation, and 18 mg/l NaOH for pH control. Detention times for the treatment units at design flow were assumed to be 30 seconds for rapid mixing and 11 minutes for flocculation. Sedimentation canals were sized for a surface overflow rate of 500 gallons per day per square foot (gpd/ft^2) at design flow and were assumed to be 20 feet deep. It was assumed that the canals would be unlined, but that the banks would be stabilized with limerock.

The bottom 5 feet of the sedimentation canals would be allocated for storage of settled solids. It was estimated that at design flow rates, sludge would need to be removed from the sedimentation canals every 2 months. Sludge was assumed to be pumped into a lined sludge lagoon for periodic removal and application on agricultural fields.

To utilize the information presented on Figure 2-1 in Chapter 2 to assist in development of design flow capacities for chemical treatment units, it was necessary to establish a projected effluent TP concentration for the technology, as currently proposed. The results of Dr. Anderson's laboratory experiments indicate that very low effluent TP concentrations, on the order of 0.01 mg/l, are possible. However, it is questionable how the technology will perform when applied in canals. It is possible that performance could suffer dramatically during high flow periods and that effluent TP concentrations could greatly exceed the 0.05 mg/l objective at times. Overall, an effluent TP concentration of 0.04 mg/l was felt to represent the proper balance between the performance capability of the technology under highly controlled conditions and the uncertainty over how performance would be affected by field conditions.

Based on the information presented on Figure 2-1 for an effluent TP concentration of 0.04 mg/l, it is unlikely that 75 percent TP removal can be achieved on a mass basis even if sufficient treatment capacity is provided to accommodate peak flow. However, for the 75 percent removal level, chemical treatment units were sized on the basis of peak flow. At the basin scale, this equates to a design capacity of 2,330 mgd. At the 50 percent and 25 percent TP removal levels, treatment capacities for basin scale facilities would be 600 and 225 mgd, respectively. Flows in excess of these amounts could be bypassed around the treatment units and the targeted TP removal levels would still be achieved. Proportionally lower treatment unit design capacities would be required at the other scales of application.

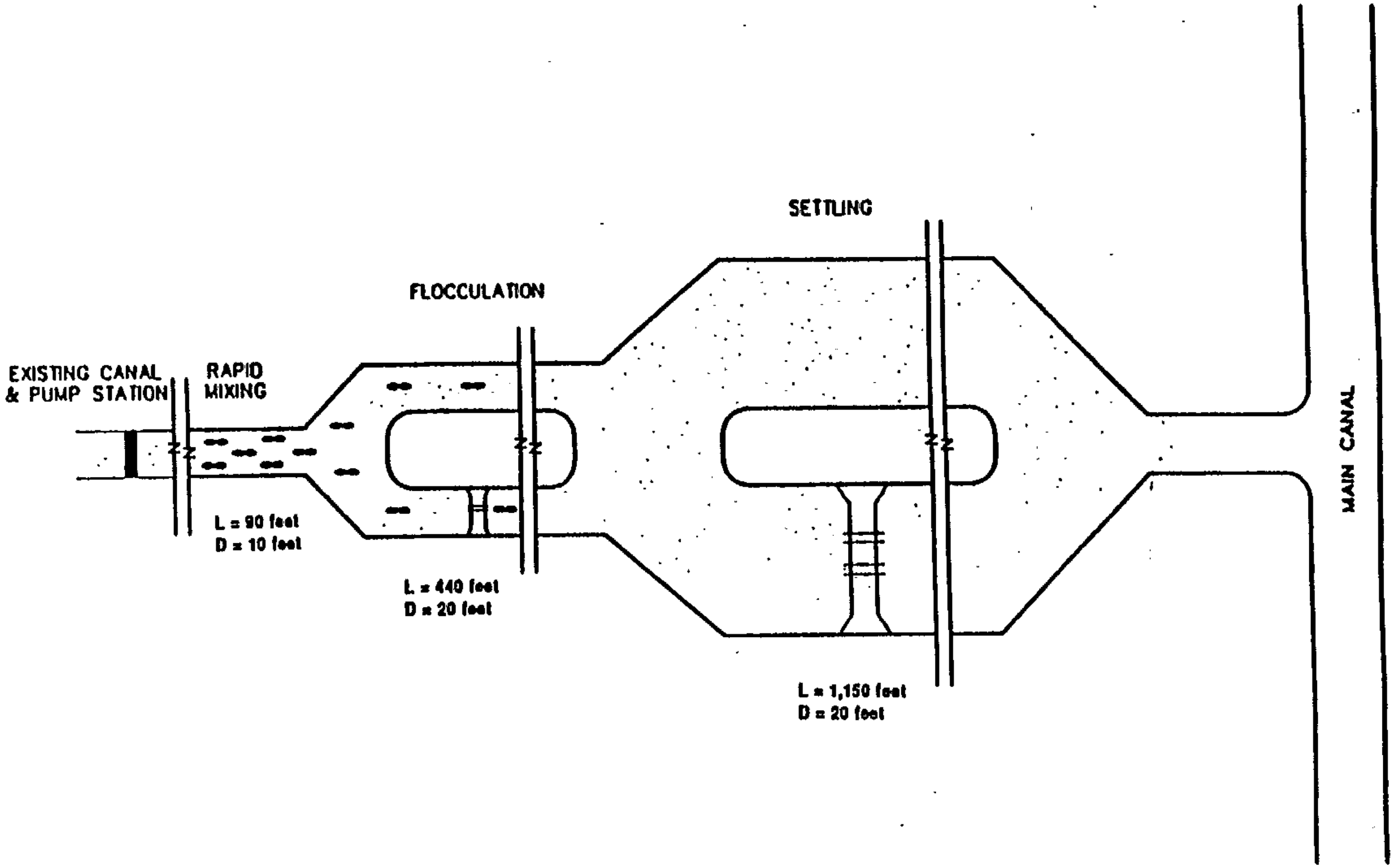

Figure 3-1
Typical Canal Configuration for Chemical Treatment
(Source: Hutcheon Engineers)

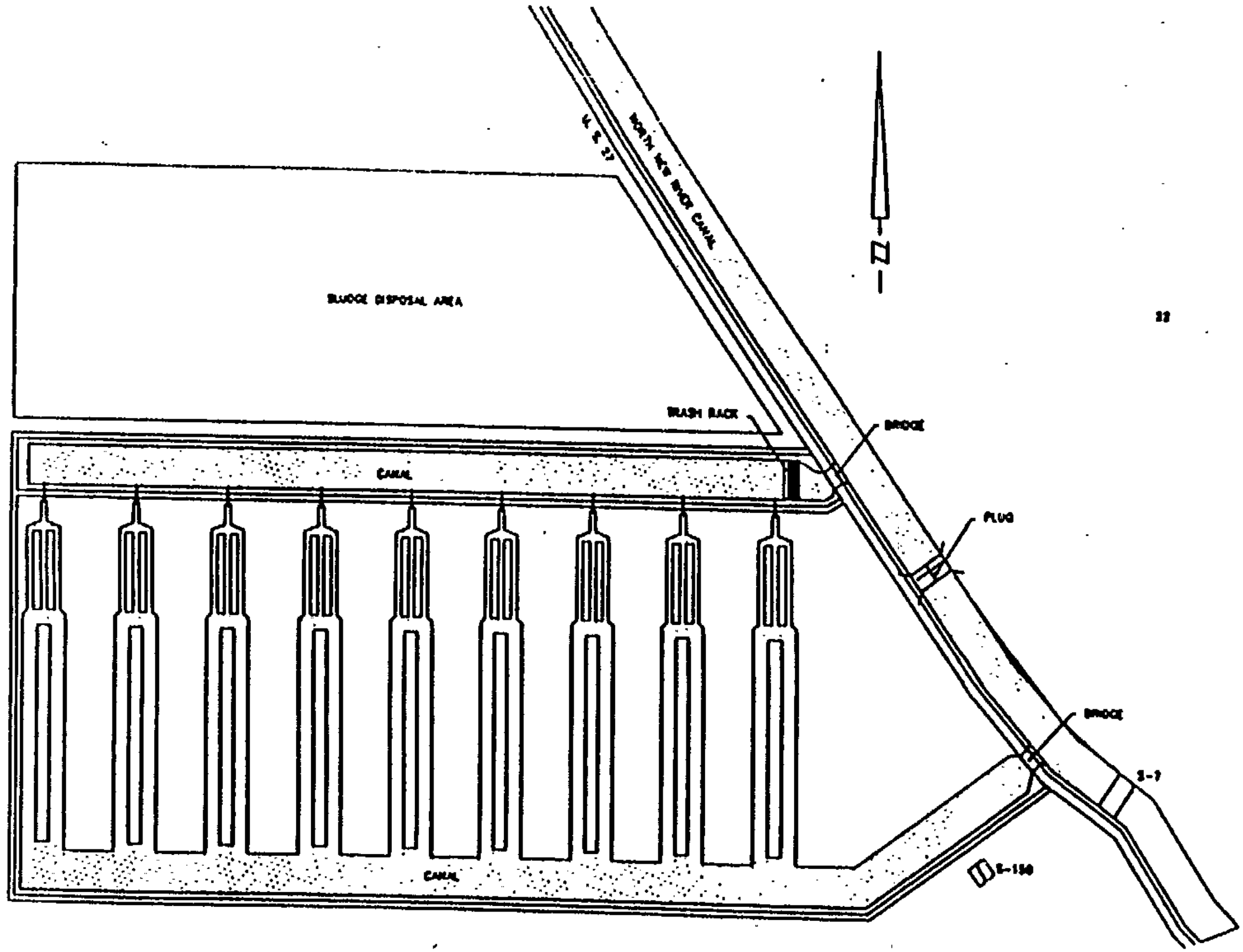

Figure 3-2
Example Configuration for a Basin Scale Chemical Treatment Facility
(Source: Hutcheon Engineers)

Presented in Table 3-1 are the design flows, treatment unit volumes, land area requirements, and capital cost estimates used as the basis of evaluation of the chemical treatment technology at the four scales of application in the EAA. Land area requirements were estimated on the basis of canal surface area, an additional similar area for construction activity, plus 25 percent for chemical storage and feed equipment, operation and maintenance facilities, and buffer areas. At the farm and point source scales of application, the 25 percent additional land area was not included since the need for buffers and dedicated operation and maintenance facilities would not be as great.

Capital costs for chemical storage and feed equipment and sludge lagoons were obtained from published cost information, verified by data from previous Brown and Caldwell projects. The cost of finished canal construction was estimated at $4 per cubic yard of canal volume, including excavation, stabilization of canal banks with limerock, and disposal of spoil material by application on adjacent land.

The unit cost for earthwork was considered representative for large projects in South Florida. No increase in the unit construction cost was assumed for small scale projects. Therefore, since most of the cost associated with implementation of the chemical treatment technology is related to earthwork, there is very little economy of scale reflected in this evaluation. This is particularly important in comparing capital costs for different levels of phosphorus reduction within an individual scale of application. The capital costs at the 25 and 50 percent removal levels could be higher in relation to the capital cost at the 75 percent removal level, if significant economy of scale in earthwork costs are realized.

Evaluation Results

The results of the evaluation of chemical treatment as an alternative technology for reducing phosphorus discharges from the EAA are summarized in Exhibit 3-1. The technology received relatively consistent scores at all scales of application.

Chemical treatment using precipitation, coagulation, and sedimentation is a demonstrated treatment technology capable of reducing phosphorus concentrations to well below 50 ppb. However, application of the technology in open canals has not been demonstrated in the field, and it is questionable whether removals to the very low levels required can be achieved reliably. Consequently, the technology, as proposed for implementation in the EAA, receives higher ratings at the lower phosphorus removal levels.

Because sophisticated construction techniques and installation of large pieces of mechanical equipment would not be involved, implementation should be possible by 1997 at all four scales of application. There should be no significant impact on hydroperiod in the Everglades, and operational impacts on the Central and South Florida (C&SF) Flood Control Project should be minor. It is assumed that the basin, subbasin, and point source scale projects will require NPDES permits, while farm scale projects will require only operating permits.

Table 3-1 Basis of Evaluation for Chemical Treatment

Parameter	Scale of application							
	Basin		Subbasin		Farm		Point source	
	Scale unit	Total EAA	Scale unit	Total EAA	Scale unit	Total EAA	Scale unit	Total EAA
Design flow, mgd								
25 percent P removal	275	1,100	28	1,100	5	865	10	70
50 percent P removal	575	2,300	58	2,300	10	1,730	15	105
75 percent P removal	2,330	9,320	233	9,320	33	6,574	20	140
Treatment volume required, million cubic feet								
25 percent P removal	10	40	1.0	40	0.2	29	0.4	2.7
50 percent P removal	23	92	2.3	92	0.4	66	0.6	4.0
75 percent P removal	93	372	9.3	372	1.5	260	0.8	5.3
Total land area, acres								
25 percent P removal	107	428	11	428	3	519	6	42
50 percent P removal	229	916	23	916	6	1,038	8	56
75 percent P removal	925	3,700	93	3,700	13	2,249	10	70
Capital cost,[a] million dollars								
25 percent P removal	17	68	3.5	140	1.0	173	1.5	10
50 percent P removal	30	120	6.0	240	1.5	260	2.2	15
75 percent P removal	88	351	17.0	680	4.2	727	2.6	18

[a] 1992 dollars.

Exhibit 3-1 Phase I Evaluation Ratings for Chemical Treatment

Criterion	Criterion weighting[a]	Scale of application/level of phosphorus reduction[b]											
		Drainage basin			Subbasin			Individual farm			Point source		
		25	50	75	25	50	75	25	50	75	25	50	75
Phosphorus removal capability	3	8/24	7/21	5/15	8/24	7/21	5/15	8/24	7/21	5/15	8/24	7/21	5/15
Implementation schedule	2	8/16	8/16	8/16	8/16	8/16	8/16	8/16	8/16	8/16	8/16	8/16	8/16
Hydroperiod impact	2	5/10	5/10	5/10	5/10	5/10	5/10	5/10	5/10	5/10	5/10	5/10	5/10
Impact on C&SF Project	2	6/12	6/12	6/12	7/14	7/14	7/14	8/16	8/16	8/16	8/16	8/16	8/16
Permitting requirements	2	3/6	3/6	3/6	3/6	3/6	3/6	5/10	5/10	5/10	4/8	4/8	4/8
Previous application of technology	2	5/10	5/10	5/10	5/10	5/10	5/10	5/10	5/10	5/10	5/10	5/10	5/10
Capital cost	1	9/9	8/8	5/5	8/8	7/7	3/3	8/8	7/7	3/3	8/8	8/8	8/8
O&M requirements	1	7/7	5/5	3/3	6/6	4/4	2/2	4/4	3/3	2/2	7/7	6/6	5/5
Economic impacts	1	10/10	9/9	8/8	10/10	9/9	8/8	9/9	8/8	8/8	9/9	9/9	9/9
Total		104	97	85	104	97	84	107	101	90	108	104	97

[a] Criteria directly related to satisfying provisions of SWIM Plan receive a weighting of 2 or 3; all other criteria receive a weighting of 1.
[b] Phosphorus reduction levels of 25, 50 and 75 percent of the influent phosphorus estimated for each scale of application.

The capital cost of the chemical treatment technology is estimated to be generally higher than the base case wetland system at the 75 percent TP removal level and generally lower at the 50 and 25 percent TP removal levels. Land requirements are significantly less than the base case wetland system, resulting in reduced economic impact on the EAA.

Operating requirements could be substantial, particularly at the higher levels of phosphorus reduction where closer attention to process variables will be required to maintain reliability. A key factor will be the frequency at which settled solids must be removed from the system to avoid excessive carryover from the settling canals.

Discussion of Evaluation Results

There is little question that chemical treatment using precipitation, coagulation, and sedimentation processes can reduce phosphorus concentrations in EAA drainage water and point source discharges to less than 50 ppb. However, there is concern about how reliably the technology will perform in ditches and canals. Also, flow and process controls throughout the treatment modules, as currently proposed, are very limited. Consequently, if treatment performance is lower than desired, there is little an operator can do quickly to correct the situation other than modify the chemical dosage or pH or reduce flow rates to the units. With the high variability of flow rates at all scales of application in the EAA and a potentially high variability in the solids concentration of the water requiring treatment, lack of process control could significantly impact treatment performance, particularly at the higher levels of phosphorus removal.

The frequency at which sludge solids will need to be removed from the settling canals represents another concern. It is expected that the chemical sludge produced will be a rather light and flocculent material with a solids content of no more than 3 percent in the canals. At that solids concentration, it is expected that the sludge storage volume in the settling canals will fill up with solids every 2 months on the average. To avoid significant solids carryover and a reduction in treatment performance, a continuous sludge removal system could be necessary. This would significantly increase the capital cost and operating requirements of the overall treatment system at all scales of application. Costs for such a sludge removal system were not included in this evaluation.

In addition to the removal of phosphorus, the chemical precipitation, coagulation, and sedimentation treatment processes have the potential to remove many other constituents, including trace elements such as metals, which are necessary to support biological communities in the Everglades. It is possible that addition of chemicals in large dosages to achieve very low phosphorus concentrations would adversely affect the chemistry of the water leaving the treatment system from the standpoint of benefit to the Everglades. This potential impact could also affect the permittability of the chemical treatment technology at the larger scales of application.

In summary, the precipitation, coagulation, and sedimentation processes are successful, proven, and capable of removing phosphorus concentrations to very low levels. However, significant questions remain regarding how the technology will perform in canals as proposed for the EAA.

The impact of limited flow and process controls and the need for frequent, if not continuous, sludge removal are specific concerns identified in this evaluation. Impacts on water chemistry also are potentially significant and should be addressed before full-scale implementation of this technology is considered. To this end, it is important that the technology be field tested during both the wet and dry seasons in the EAA to determine treatment performance at different hydraulic and phosphorus loading rates and under a variety of hydrologic and background environmental conditions.

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LIMEROCK SORPTION

Limerock, or limestone, is calcium carbonate ($CaCO_3$). It has been demonstrated in the laboratory that phosphorus can be removed from farm runoff by contact with the limerock.[4] Several removal mechanisms have been postulated, including adsorption and precipitation, but the predominant mechanism is not known.

Limerock is readily available, since it underlies much of the EAA. Significant removals of phosphorus might be accomplished if the farm runoff could be brought into contact with the limestone in engineered systems. Currently, the limerock sorption alternatives are not envisioned as stand-alone treatment units. Rather, they are seen as pretreatment systems to be operated at the farm scale or to treat discharges from point sources to reduce phosphorus loads on downstream facilities.[5]

Overview of Technology

Several alternative limerock systems have been suggested. Each seeks to enhance contact between the limerock and farm runoff. The systems include:

1. Ditches or canals dug down into the limestone layer (see Figure 3-3a). Phosphorus removal occurs as the water contacts the sides and bottoms of these channels.

2. The same ditches or canals partially filled with crushed limerock (see Figure 3-3b). The crushed limerock provides additional contact surface for phosphorus removal.

3. Parallel treatment canals. A treatment canal is constructed parallel to the main farm canal but at a higher elevation (see Figure 3-4). The beds of both canals are in the limerock strata. Water from the main canal is pumped into the treatment canal. It percolates back through the limestone strata to the main canal under the impetus of the difference in head between the two systems. The rock strata may be fractured with dynamite to increase limerock specific surface and permeability.

4. Cascade system. Water is recirculated over tiers of crushed limerock (see Figure 3-5).

Limerock has a finite phosphorus removal capacity. When this capacity is exhausted, the limerock must either be regenerated or replaced with fresh limerock. Regeneration appears impractical since there is not a proven method for collecting the phosphorus-laden waste from the regeneration process. Limerock replacement is the more likely prospect.

Investigators have conducted several laboratory experiments in attempts to define the phosphorus removal capability of limerock. Dr. K. R. Reddy of the University of Florida equilibrated orthophosphate-containing waters with finely-ground caprock from the Knight's Farm area to develop the adsorption isotherms shown on Figure 3-6. The data show that low phosphorus concentrations could be achieved, but the limerock's adsorption capacity was low at these concentrations. The adsorption capacity of the crushed limerock likely to be used in full-scale

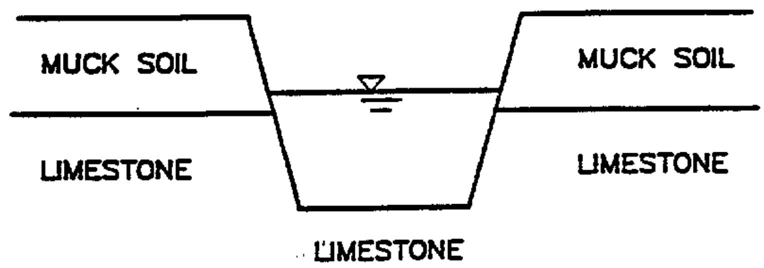

Figure 3-3(a)
Canal Excavated Into Limestone

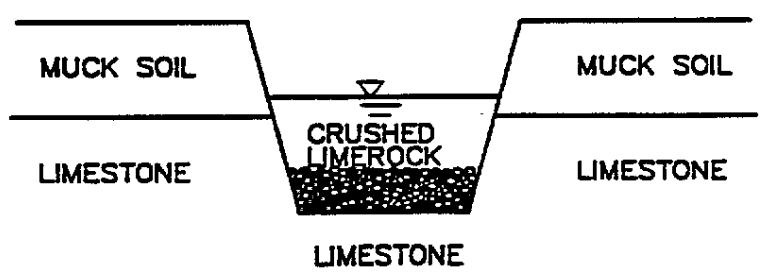

Figure 3-3(b)
Canal Partially Filled with Crushed Limerock
(Source: W.R. Patrick, Jr., Louisiana State University)

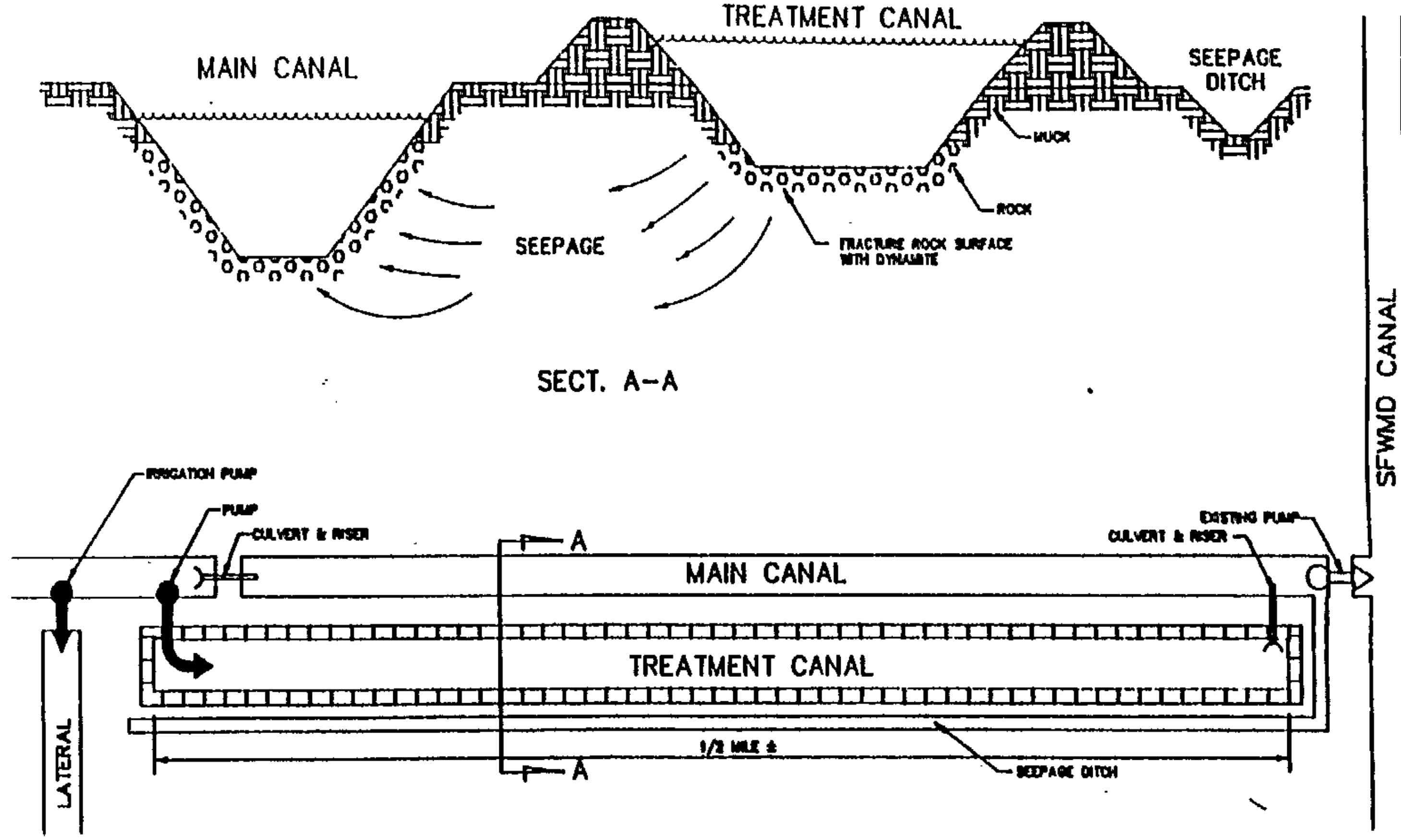

Figure 3-4
Parallel Treatment Canals for Limerock Sorption
(Source: Hutcheon Engineers)

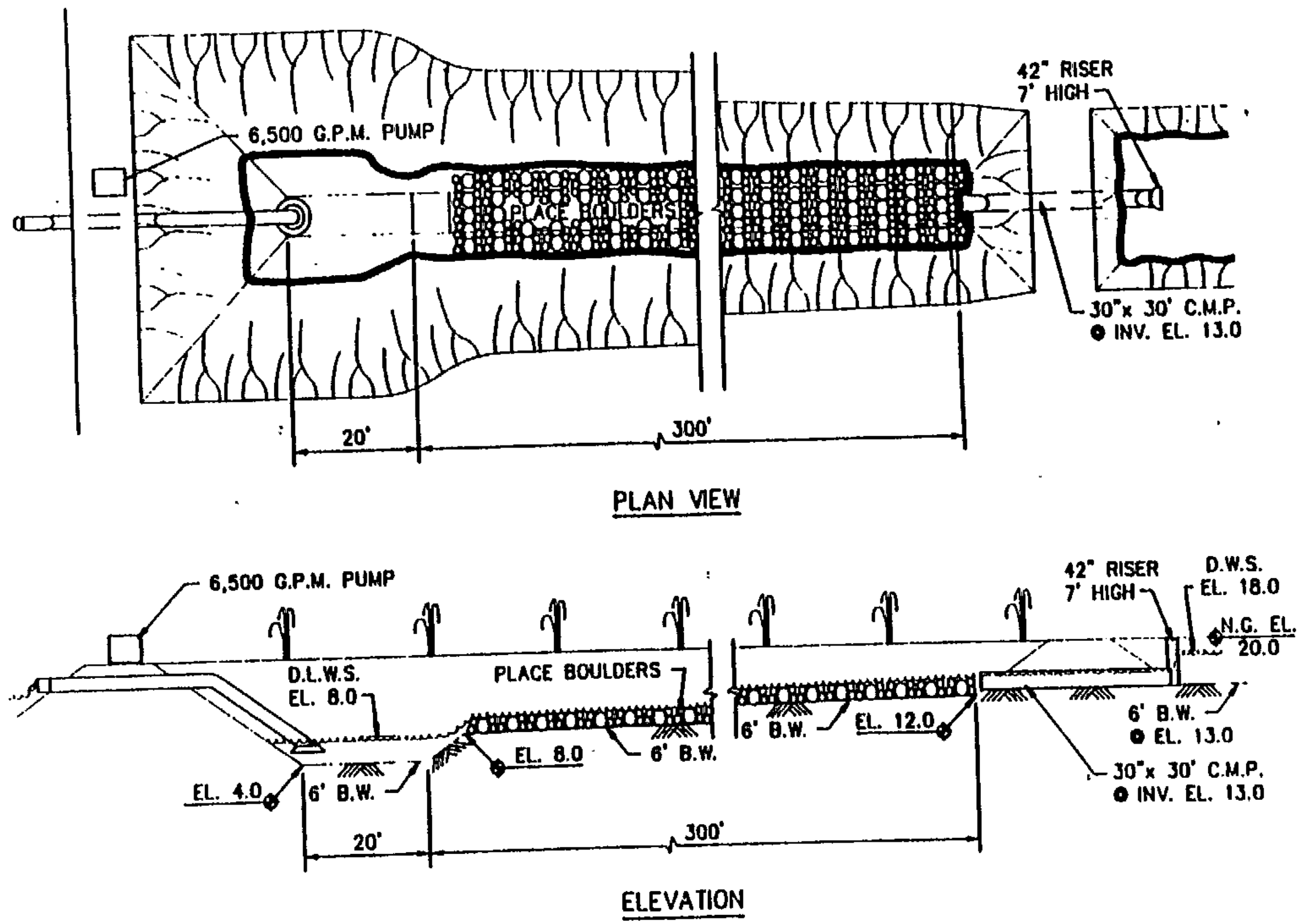

Figure 3-5
Cascade Treatment System for Limerock Sorption
(Source: Hutcheon Engineers)

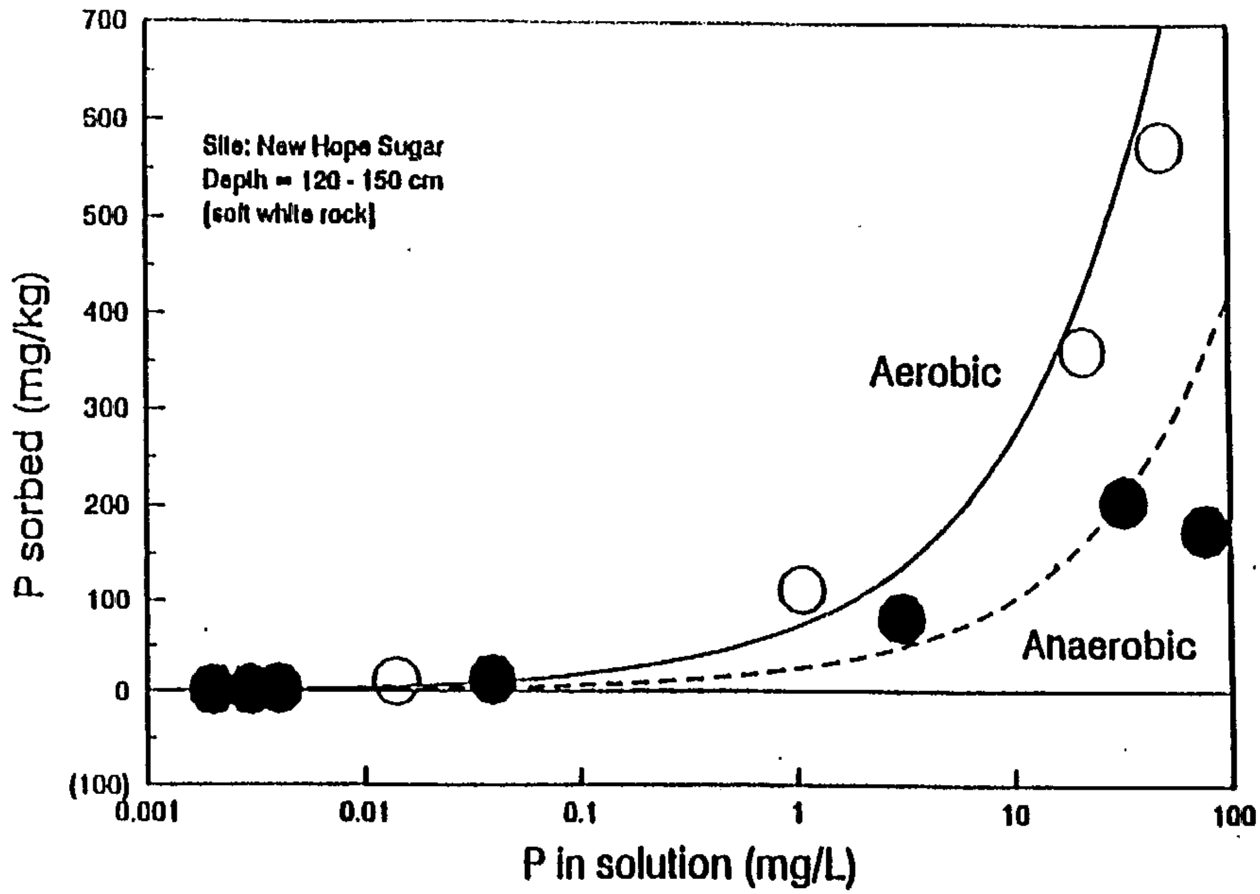

Figure 3-6
Adsorption Isotherms for Limerock Sorption
(Source: K.R. Reddy, University of Florida)

treatment systems will probably be less than shown on Figure 3-6, because the crushed limerock will have a lower specific surface than the finely-ground limerock used in the Reddy experiments. The data suggest that limerock usage will be high.

Dr. William Patrick of the Louisiana State University (LSU) Wetland Biochemistry Institute conducted a second experiment in which phosphorus was reduced from 0.2 mg/l to less than 0.05 mg/l in less than 1 day after being contacted with undisclosed weights of crushed limestone of various sizes.

Dr. Patrick conducted a third experiment in which 500-gram samples of three different types of limerock were contacted with 1,500 milliliters (ml) of solution containing 10 mg/l phosphorus, as P. This concentration is higher than anticipated for most scales of application in the EAA. It was used to determine the limerock's capacity to remove large amounts of phosphorus. Phosphorus was reduced to 2, 4, and 8 mg/l P after 10 days of contact with a hard caprock sample, a sand-marl sample, and an intermediate hardness sample composed of cemented shells, respectively. The researchers extended the experiments to see if further phosphorus reductions could be obtained. Results from the extended experiments are not yet available.

In a fourth experiment, a dilute solution of orthophosphate (1.9 mg/l, as P) was allowed to flow through a thin horizontal bed of limerock, 10 centimeters deep, simulating overland flow. The researchers estimated a contact time of 1 day based on 50 percent void volume. The phosphorus concentration was reduced to about 0.5 mg/l. The average removal rate was 0.07 grams per square meter per day. This rate appeared to be maintained throughout most of the 11-day experiment, with perhaps a slight reduction in removal rate during the last few days.

Dr. Patrick and the U.S. Sugar Corporation recently conducted pilot-scale field tests of limerock sorption at the U.S. Sugar mill in Clewiston, Florida. The pilot system is reported to be a 900-foot-long canal, 8 to 10 feet wide, filled with about 2 feet of crushed limerock.[5] Experiments have been conducted to determine the capacity of the crushed limerock to remove phosphorus at different flow rates and contact times. However, no data from these experiments have been reported to date.

Basis for Evaluation

Data from the overland flow experiment were used as the basis for this evaluation. The overland flow experiment comes closest to simulating systems that could be used at full scale. These include passing flow through canals excavated into the limerock or passing flow through ditches filled with crushed limerock. The latter system is the model for this evaluation. The calculations are conceptual, because none of the laboratory experiments accomplished thus far have actually simulated any of the full-scale systems.

Assuming the phosphorus removal efficiency demonstrated in the overland flow experiments would apply at any level of influent phosphorus concentration, we assumed that a 1-day contact time (based on crushed limerock void volume) would produce a 75 percent phosphorus reduction. If phosphorus removal efficiency is dependent on influent concentration, then this assumption is probably optimistic, since the EAA phosphorus concentrations are considerably less (0.15 to 1.0 mg/l) than the phosphorus concentration of the overland flow experiments (1.9 mg/l).

Treatment channels were sized to achieve 75 percent phosphorus removal, based on a 1-day contact time and a target effluent concentration of 0.04 mg/l. Using the methodology presented in Chapter 2, treatment capacities required to achieve overall phosphorus removal levels of 75, 50, and 25 percent were computed. Flows in excess of required treatment capacity were assumed to be bypassed.

We assumed all channels would be 20 feet wide at the bottom, 10 feet deep, and would have side slopes of 1.5 feet horizontal length for every foot of vertical rise. Excavated limerock would be crushed at the site using mobile crushing equipment and used to create the adsorptive bed in the channel. The channel would be filled to within 2 feet of the top with crushed limerock having a 50 percent void volume. For the purpose of this evaluation, we assumed the crushed limerock would have the same adsorptive capacity as the limerock used in the overland flow experiment. The limerock would be removed and replaced when saturated with phosphorus.

A summary of the information used in the evaluation of the limerock sorption technology is presented in Table 3-2. Included in the table are design flow rates, required channel lengths and land areas, and capital costs for the four scales of application and three levels of phosphorus removal being considered in this evaluation. Land area requirements were based on required channel area and a 100-foot-wide construction zone on each side of the channel. An additional 10 percent was included for buffer areas and operation and maintenance facilities.

Costs for channel construction were based on a combined unit cost of $5.75 per cubic yard of channel volume. This included excavation and disposal (on-site) of muck soil, excavation of limerock from the channel, crushing of the limerock using mobile crushing equipment, and placement of the crushed limerock in the completed channel. The total cost for channel construction was estimated to be $573,000 per mile including land acquisition and engineering.

Evaluation Results

The evaluation ratings given to limerock sorption are presented in Exhibit 3-2. The technology receives generally low marks, reflecting concern about its phosphorus removal capability, lack of previous application, and ability to be implemented by 1997. Operating requirements may be significant depending on the limerock's adsorptive capacity and how often the limerock in the channels must be replaced. The evaluation was limited by lack of experimental data derived from systems similar to those proposed for full-scale application. It may be appropriate to reevaluate this technology when data from U.S. Sugar's pilot-scale treatment system become available.

The technology received its highest rating for treatment of point sources, primarily due to reduced capital costs and lower land requirements to achieve desired phosphorus removals. This advantage derives from the fact that point source flows are much lower than flows from other sources and, therefore, required treatment unit volumes are greatly reduced. The limerock

Table 3-2 Basis of Evaluation for Limerock Sorption

Parameter	Scale of application							
	Basin		Subbasin		Farm		Point source	
	Scale unit	Total EAA	Scale unit	Total EAA	Scale unit	Total EAA	Scale unit	Total EAA
Design flow, mgd								
25 percent P removal	225	900	23	900	4	640	5	35
50 percent P removal	600	2,400	60	2,400	10	1,695	10	70
75 percent P removal	2,330	9,320	233	9,320	33	5,709	15	105
Channel length, miles								
25 percent P removal	22	88	2	92	0.4	63	0.5	3
50 percent P removal	59	236	6	237	1.0	168	1.0	7
75 percent P removal	231	924	23	921	3.8	651	1.5	10
Land area, acres								
25 percent P removal	660	2,640	69	2,760	11	1,868	15	105
50 percent P removal	1,770	7,080	177	7,080	29	5,034	30	208
75 percent P removal	6,930	27,720	690	27,600	113	19,549	45	313
Capital cost,[a] million dollars								
25 percent P removal	13	50	1	53	0.2	36	0.3	2
50 percent P removal	34	135	3	135	0.6	97	0.6	4
75 percent P removal	132	529	13	527	2.8	475	0.9	6

[a] 1992 dollars.

Exhibit 3-2 Phase I Evaluation Ratings for Limerock Sorption

Criterion	Criterion weighting[a]	Scale of application/level of phosphorus reduction[b]											
		Drainage basin			Subbasin			Individual farm			Point source		
		25	50	75	25	50	75	25	50	75	25	50	75
Phosphorus removal capability	3	3/9	2/6	1/3	3/9	2/6	1/3	3/9	2/6	1/3	4/12	3/9	2/6
Implementation schedule	2	2/4	1/2	1/2	2/4	1/2	1/2	3/6	1/2	1/2	6/12	2/4	2/4
Hydroperiod impact	2	6/12	6/12	6/12	6/12	6/12	6/12	6/12	6/12	6/12	6/12	6/12	6/12
Impact on C&SF Project	2	6/12	6/12	6/12	7/14	7/14	7/14	8/16	8/16	8/16	8/16	8/16	8/16
Permitting requirements	2	3/6	3/6	3/6	3/6	3/6	3/6	5/10	5/10	5/10	4/8	4/8	4/8
Previous application of technology	2	1/2	1/2	1/2	1/2	1/2	1/2	2/4	2/4	2/4	2/4	2/4	2/4
Capital cost	1	8/8	7/7	3/3	8/8	7/7	3/3	9/9	8/8	4/4	9/9	8/8	7/7
O&M requirements	1	8/8	7/7	6/6	7/7	6/6	5/5	6/6	5/5	4/4	8/8	7/7	6/6
Economic impacts	1	8/8	8/8	6/6	8/8	8/8	6/6	8/8	8/8	8/8	6/6	6/6	6/6
Total		69	62	52	70	63	53	80	71	63	87	74	69

[a] Criteria directly related to satisfying provisions of SWIM Plan receive a weighting of 2 or 3; all other criteria receive a weighting of 1.
[b] Phosphorus reduction levels of 25, 50 and 75 percent of the influent phosphorus estimated for each scale of application.

Exhibit 3-2 Phase I Evaluation Ratings for Limerock Sorption

Criterion	Criterion weighting[a]	Scale of application/level of phosphorus reduction[b]											
		Drainage basin			Subbasin			Individual farm			Point source		
		25	50	75	25	50	75	25	50	75	25	50	75
Phosphorus removal capability	3	3/9	2/6	1/3	3/9	2/6	1/3	3/9	2/6	1/3	4/12	3/9	2/6
Implementation schedule	2	2/4	1/2	1/2	2/4	1/2	1/2	3/6	1/2	1/2	6/12	2/4	2/4
Hydroperiod impact	2	6/12	6/12	6/12	6/12	6/12	6/12	6/12	6/12	6/12	6/12	6/12	6/12
Impact on C&SF Project	2	6/12	6/12	6/12	7/14	7/14	7/14	8/16	8/16	8/16	8/16	8/16	8/16
Permitting requirements	2	3/6	3/6	3/6	3/6	3/6	3/6	5/10	5/10	5/10	4/8	4/8	4/8
Previous application of technology	2	1/2	1/2	1/2	1/2	1/2	1/2	2/4	2/4	2/4	2/4	2/4	2/4
Capital cost	1	8/8	7/7	3/3	8/8	7/7	3/3	9/9	8/8	4/4	9/9	8/8	7/7
O&M requirements	1	8/8	7/7	6/6	7/7	6/6	5/5	6/6	5/5	4/4	8/8	7/7	6/6
Economic impacts	1	8/8	8/8	6/6	8/8	8/8	6/6	8/8	8/8	8/8	6/6	6/6	6/6
Total		69	62	52	70	63	53	80	71	63	87	74	69

[a] Criteria directly related to satisfying provisions of SWIM Plan receive a weighting of 2 or 3; all other criteria receive a weighting of 1.
[b] Phosphorus reduction levels of 25, 50 and 75 percent of the influent phosphorus estimated for each scale of application.

SEDIMENTATION IN LIMESTONE BORROWS

Over the years, limestone borrow areas, or rock pits, have been excavated in South Florida to provide a source of construction-grade limerock to support projects throughout Florida. Excavation of deep borrow areas in conjunction with urban land development projects in Dade, Broward, and Palm Beach Counties has been accomplished over the last 30 years. The deep lakes that result from the borrow areas are often made an integral part of the project stormwater management system. It has been recognized that the porous limestone exposed on the sides of the lakes, combined with the fine sediments which accumulate on the lake bottoms, helps to treat stormwater by precipitation and adsorption.

The Florida Sugar Cane League has proposed that limestone borrow areas be used as a treatment method to remove phosphorus from EAA stormwater runoff. Some treatment in the borrow area could occur from natural sedimentation and chemical precipitation and adsorption processes. However, for the purposes of this evaluation, it is assumed that the borrow areas will serve as large man-made sedimentation basins located downstream of chemical treatment facilities similar to those discussed previously in this chapter.

Overview of Technology

It is recognized that rock pits have the capability to assist with the treatment of stormwater or wastewater discharges. This is accomplished with the rock pit serving as a wet detention/ retention basin for stormwater management systems or as a final wastewater treatment unit using dilution and the inactivation capabilities of the limestone. Inflow volumes of stormwater for typical design events are approximately 10 to 15 percent of the total pit water volume. Wastewater inflow volumes make up a smaller percentage but tend to occur more consistently.

Typical stormwater and wastewater inflows are diluted, treated by the alkaline waters, and eventually merged with groundwater after moving through the porous limestone walls. Transmissivity values of the porous limestone found in the Biscayne Aquifer can be very high, on the order of 500,000 square feet per day.[7] The rock pits typically are not connected directly to District drainage canals since the water in their deeper zones usually does not meet Florida's surface water quality criterion for dissolved oxygen. Overflow structures or discharge pump stations often are installed in these facilities to accommodate extreme stormwater inflow events.

The study completed in December 1991 by the Florida Atlantic University/Florida International University Joint Center for Environment and Urban Problems on the use of a deep limerock pit as an advanced wastewater treatment facility[7] makes the following points:

1. Because rock pit waters have a high rate of phytoplankton productivity, which produces oxygen, the pits are well oxygenated to a depth of at least 15 feet (deeper in winter), even after receiving groundwater, treated wastewater effluent, and surface drainage. Sufficient oxygen is generated to meet COD and BOD demands with a considerable oxygen surplus.

2. With high oxygen and pH (usually between 8 and 9), heavy metals are removed from solution by chemical precipitation. The metal hydroxides are further complexed in the anoxic, calcium carbonate clay and silt sediments as insoluble sulfides. The lime-mud aquiclude thus prevents the heavy metals from percolating. Dissolved phosphates are subject to calcium complexation, precipitation, and sediment incorporation. Phosphate transfer to the sediments also is enhanced by the sinking of phytoplankton-produced organic matter from the surface waters. Nitrogen also is reduced in this fashion.

3. A rock pit contains an active nitrogen cycle. Nitrifying bacteria ultimately convert ammonium to nitrate. In anoxic bottom waters and sediments, denitrifying bacteria convert nitrate to gaseous nitrogen forms, which ultimately are lost to the atmosphere. This prevents a buildup of fixed nitrogen in the pit.

4. Pollutant inactivation and precipitation by adsorption is a pit treatment factor.

5. Deep, stratified, steep-sided, alkaline rock pits naturally are resistant to harmful eutrophication because of nutrient complexation and removal. The steep sides allow very little area for the growth of attached aquatic vegetation.

Recognizing that limerock pits have some natural water treatment capabilities, the use of a similar approach for treating EAA discharges was evaluated. The large discharge volumes which occur on the basin and subbasin levels will require excavation of large rock pits to accommodate peak flows. Peak daily discharges from the EAA have the capability to exchange fully the water in a rock pit in a matter of hours. If this occurs, the alkaline rock pit water would be displaced and the natural treatment capabilities of the rock pit would be dramatically reduced. It was therefore recognized that use of rock pits would require some supplemental treatment for large-scale discharges. At the basin and subbasin scales, it was assumed that a chemical precipitation, coagulation, and sedimentation process would be used, with the excavated borrow area serving as a large sedimentation basin. A similar assumption was also made for evaluation of rock pit treatment at the farm and point source scales, although some of the existing quarries located within or adjacent to the EAA may be of sufficient size to provide natural treatment without the chemical pretreatment process.

This technology is similar to the chemical treatment technology discussed previously except that excavated rock pits are used as the sedimentation basins. Chemicals such as ferric salts, lime, polymer, and sulfuric acid would be added to the water being treated. Pretreatment processes would include rapid mixing and flocculation similar to that described previously for the chemical treatment alternative.

<u>Basis of Evaluation</u>

Assuming that a sufficient number of limestone borrow areas can be excavated at appropriate locations, their use as sedimentation basins in conjunction with chemical treatment facilities can be applied at all scales in the EAA. The rock pits would be expected to provide somewhat better solids removal performance than the sedimentation canals in the chemical treatment alternative discussed previously because of the reduced potential for scour during peak flow conditions. It has been assumed for this evaluation that chemical treatment, when used in conjunction with limestone borrows for sedimentation, is capable of achieving an effluent TP concentration of 0.03 mg/l. On the basis of the information presented in Chapter 2, a treatment capacity of 1,250 mgd is required at this effluent TP concentration to achieve an overall TP removal level of 75 percent at the basin scale. For 50 and 25 percent TP removal at the basin scale, treatment capacities of 500 and 200 mgd are required, respectively. Proportionally lower capacities are required at the smaller scales of application.

Chemical feed, rapid mix, and flocculation processes were sized to accommodate the appropriate design flow for the phosphorus removal level desired. Flows in excess of design flow were assumed to be bypassed directly to the rock pits. Rock pits were assumed to handle peak flows for all phosphorus removal levels at all scales of application. Table 3-3 summarizes the flows, land area requirements, and capital costs used in the Phase I evaluation of this technology. Sizing criteria for the chemical precipitation and flocculation processes were assumed to be the same as discussed previously for the chemical treatment technology.

An assumption was made that the chemical treatment facilities and rock pit sedimentation basins would be constructed in close proximity to basin and subbasin discharge points to minimize the requirement for modifications to the existing stormwater conveyance system. Identification of potential sites is beyond the scope of this Phase I evaluation. The depth of the rock pits was assumed to be 20 feet as presented in a report prepared by Hutcheon Engineers.[6] Deeper excavations may be preferable to reduce the effects of currents and gradients that could cause resuspension of sediments. Deeper excavations would also increase sludge storage capacity.

The Hutcheon report based rock pit surface area on a minimum detention time of 4 hours in the rock pit at peak flow.

We believe a more appropriate sizing criterion for rock pit surface area would be surface loading rate, similar to that used in sizing sedimentation basins for water and wastewater treatment plant applications. A relatively low surface loading rate of 500 gallons per day per square foot (gpd/ft^2) of settling area would probably be appropriate for the rock pits. Peak flows, rather than the design flows for the chemical treatment processes, were used to size the pits at the various scales. The greater flow rate was used to compensate for short circuiting, currents, and other factors that may affect settling rates in a large, uncontrolled settling basin. Treatment performance would probably be enhanced further if excavation depths of 30 or 40 feet were used also. The Florida Sugar Cane League is planning a full-scale pilot study to test the treatment performance of rock pits on EAA drainage water. This research will provide additional information on how to properly size and configure rock pits as treatment units. For this initial evaluation, however, sizing was accomplished using a surface loading rate of 500 gpd/ft^2. Using this method, a settling area of approximately 107 acres is required at the drainage basin scale. Settling areas of 10.7, 1.5, and 0.9 acres are required at the subbasin, farm, and point source scales, respectively. Overall land requirements for the rock pits were assumed to be two times the settling area.

Table 3-3 Basis of Evaluation for Sedimentation in Limestone Borrows

Parameter	Scale of application							
	Basin		Subbasin		Farm		Point source	
	Scale unit	Total EAA	Scale unit	Total EAA	Scale unit	Total EAA	Scale unit	Total EAA
Design flow,[a] mgd								
25 percent P removal	200	800	20	800	3	519	10	35
50 percent P removal	500	2,000	50	2,000	8	1,384	15	70
75 percent P removal	1,250	5,000	125	5,000	20	3,460	20	105
Rock pit (settling) volume,[b] million cubic feet								
25 percent P removal	93	373	9.3	373	1.3	228	1.3	9.2
50 percent P removal	93	373	9.3	373	1.3	228	1.3	9.2
75 percent P removal	93	373	9.3	373	1.3	228	1.3	9.2
Total land area, acres								
25 percent P removal	250	1,000	25	1,000	7	1,200	9	65
50 percent P removal	340	1,360	34	1,360	9	1,560	12	84
75 percent P removal	550	2,200	55	2,200	11	1,900	15	104
Capital cost,[c] million dollars								
25 percent P removal	17	68	3.0	120	0.9	163	1.8	12
50 percent P removal	33	132	6.0	240	1.6	277	2.5	18
75 percent P removal	62	248	12.0	480	3.0	519	3.0	21

[a] Design flow of chemical treatment facilities; rock pits to accommodate peak flow at all scales of application and phosphorus removal levels.
[b] Based on a surface loading rate of 500 gpd/ft^2 and a depth of 20 feet.
[c] 1992 dollars.

The capital costs presented in Table 3-3 include costs for land, chemical treatment facilities, and excavation of the limestone borrow areas themselves. It is possible that some revenue could result from sale of the limerock excavated from the pits. However, this cannot be assumed, particularly if the pits are located near drainage discharges and some distance away from where the limerock would be used for construction. Additional cost could be realized for construction of canal systems to convey water from existing drainage discharge points to the rock pits. However, without location information, it is not possible to estimate the magnitude of these costs at this time. For the purposes of this Phase I evaluation, the cost of systems to convey water to and from the rock pits was assumed to be 25 percent of the pit excavation cost.

Evaluation Results

Presented in Exhibit 3-3 are the ratings given to chemical treatment using rock pits as sedimentation basins. The technology received its highest ratings at the individual farm and point source scales, although the ratings were relatively uniform at all four scales of application. Generally, this technology received slightly higher ratings at the 75 percent phosphorus removal level than did the chemical treatment technology using sedimentation canals. The primary reason for this is the expected increase in settling performance in the pits, particularly if they are excavated to depths of 30 or 40 feet. The anticipated difficulty in obtaining permits for the rock pits resulted in a low rating against that criterion.

Discussions of Evaluation Results

This technology is similar to the chemical treatment process with sedimentation canals. The only difference is the use of rock pits as settling basins. Assuming proper sizing and design of the chemical treatment facilities and proper sizing and configuration of the rock pits, this technology has the capability to reduce phosphorus concentrations to below 0.05 mg/l. Effluent TP concentrations on the order of 0.03 mg/l are considered achievable. Aspects of the technology which warrant further evaluation include criteria for sizing and configuring the rock pits as treatment units, sludge removal and disposal, potential siting of the rock pits in relation to drainage water discharges and future construction projects, and resolution of the many permitting issues which could make excavation of large limestone borrow areas difficult to implement for treatment purposes.

Sludge removal would need to be accomplished using a hydraulic dredge or similar equipment. No special provisions to dewater the material were considered. However, sludge lagoons were assumed to be located near the rock pits to provide for additional short-term storage capacity. It was assumed that land application disposal would be accomplished, either on agricultural fields or on land dedicated for that purpose.

The South Florida Mining Coalition converts approximately 300 to 400 acres to limestone quarries annually. Sufficient time and equipment are available to perform the work prior to the 1997 completion date. Installation of related treatment facilities may take as long or longer than the actual rock pit excavation if custom-fabricated treatment facilities are required to accommodate large flow volumes. Project implementation by 1997 is achievable.

Exhibit 3-3 Phase I Evaluation Ratings for Sedimentation in Limestone Borrows

Criterion	Criterion weighting[a]	Scale of application/level of phosphorus reduction[b]											
		Drainage basin			Subbasin			Individual farm			Point source		
		25	50	75	25	50	75	25	50	75	25	50	75
Phosphorus removal capability	3	8/24	7/21	6/18	8/24	7/21	6/18	8/24	7/21	6/18	8/24	7/21	6/18
Implementation schedule	2	7/14	7/14	7/14	7/14	7/14	7/14	8/16	8/16	8/16	9/18	9/18	9/18
Hydroperiod impact	2	5/10	5/10	5/10	5/10	5/10	5/10	5/10	5/10	5/10	5/10	5/10	5/10
Impact on C&SF Project	2	6/12	6/12	6/12	7/14	7/14	7/14	8/16	8/16	8/16	8/16	8/16	8/16
Permitting requirements	2	2/4	2/4	2/4	2/4	2/4	2/4	2/4	2/4	2/4	2/4	2/4	2/4
Previous application of technology	2	6/12	6/12	6/12	6/12	6/12	6/12	6/12	6/12	6/12	6/12	6/12	6/12
Capital cost	1	9/9	8/8	7/7	8/8	7/7	4/4	8/8	7/7	4/4	8/8	8/8	8/8
O&M requirements	1	8/8	6/6	4/4	7/7	5/5	3/3	5/5	4/4	3/3	7/7	6/6	5/5
Economic impacts	1	8/8	8/8	8/8	8/8	8/8	8/8	8/8	8/8	8/8	9/9	9/9	9/9
Total		101	95	89	101	95	87	103	98	91	108	104	100

[a] Criteria directly related to satisfying provisions of SWIM Plan receive a weighting of 2 or 3; all other criteria receive a weighting of 1.
[b] Phosphorus reduction levels of 25, 50 and 75 percent of the influent phosphorus estimated for each scale of application.

Impacts on hydroperiod are expected to be minimal at the basin and subbasin scales. Use of this technology for the smaller scale systems has the potential to reduce peak surface water discharges through retention of runoff from more frequent storms. If anything, this should have a positive impact on hydroperiod in the Everglades.

It is not expected that the limestone borrow alternative will prompt any substantive changes to the Central and South Florida Flood Control Project at any scale. This assumes that the treatment element for the basin and subbasin systems will handle or bypass peak flows reliably, minimizing the potential for increased flood stages.

Use of rock pits as wet detention stormwater management systems is frequently accomplished in South Florida's urban areas. A similar approach is feasible at a farm scale or possibly for a point source with reasonable inflow rates and phosphorus concentrations. The few studies which have been accomplished on these systems have not detected any significant pollutant migration into the contiguous aquifer. However, an FDER water quality variance may be required if a direct connection to groundwater is made.

The current NPDES stormwater permit exemption for agricultural systems may provide a mechanism to avoid EPA permitting for farm scale systems. Traditional NPDES permits will be required should the chemical treatment process be included. Dredge and fill permits will be required for all excavations greater than 1/2 acre in size, if isolated, and for any size excavation if connected to waters of the state. The Corps of Engineers, the District, the FDER, and Palm Beach County all participate in this permitting process. Palm Beach County also has an excavation ordinance that will impose additional construction requirements on the rock pits. In general, permitting for basin, subbasin, and point source scale excavations is expected to be complicated and controversial.

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PERCOLATION PONDS

Percolation ponds have been used as a method of wastewater treatment and disposal in Florida for many years. Advantages of percolation ponds include simplicity of operation, dampening of peak flows, and reduction of suspended solids and other pollutants to the receiving waters. Disadvantages include the need for periodic removal of accumulated sediments in the pond, replacement of soil media used for percolation, and the potential for contamination of the soil mantle and groundwater. Percolation ponds have been constructed at some of the sugar mills in the EAA for treatment of process wastewater. They also have been proposed for treating drainage water from the EAA.

Overview of Technology

Percolation ponds remove particulate phosphorus by sedimentation. Soluble organic phosphorus is removed by adsorption and chemical precipitation/filtration in the soil profile through which the wastewater percolates. Flow from percolation ponds in the EAA would be horizontal through pond dikes towards perimeter canals. A sectional view of a typical percolation pond is illustrated on Figure 3-7. This horizontal flow scheme is required due to the presence of a limestone caprock 5 to 10 feet below the ground surface that retards vertical percolation and limits the depth of soil profile available for phosphorus removal. Higher levels of phosphorus removal in the soil profile can be achieved by constructing wide levees, and allowing the flow being treated to percolate horizontally to a perimeter canal.

An important design consideration for percolation ponds is the minimum distance needed between the ponds and perimeter canals to reduce phosphorus concentrations to required levels. A pilot test was conducted by CH_2M Hill for the Florida Sugar Cane League at U.S. Sugar Corporation's Clewiston Mill to determine phosphorus uptake rates of soils in this area of the EAA and to estimate the length of time that soils can be expected to provide the required level of treatment before the uptake capacity is exhausted.

Most of the data were collected weekly from November 1989 to March 1990 during the 1989-1990 sugar cane milling season. Water quality was monitored in the pilot pond and perimeter canal during the test period to determine the capacity of the soils to reduce phosphorus levels. Preliminary findings indicated the following:

- Soils appeared to have a significant capacity to attenuate phosphorus.
- The minimum distance between percolation ponds and perimeter canals to reduce phosphorus levels to targeted levels was between 150 to 300 feet.
- Recycling of process water causes the phosphorus concentration in the wastewater to increase.

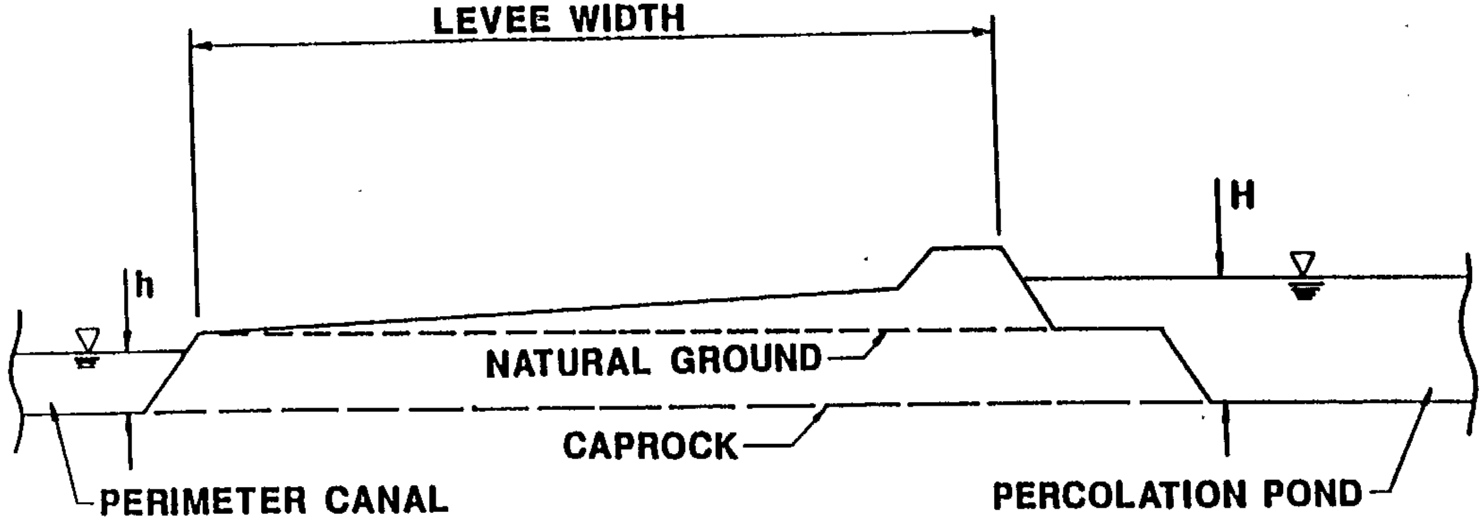

Figure 3-7
Typical Levee Section of Percolation Ponds

Estimates of levee width for various levels of phosphorus reduction can be calculated using the following formula recommended by the U.S. Environmental Protection Agency (EPA) for the design of percolation ponds:[12]

$$C_x = C_o * e^{-kt} \tag{1}$$

where: C_o = Concentration in percolation pond, mg/l

C_x = Concentration in perimeter canal, mg/l

$t = xv/i$

x = levee width, feet

v = soil volumetric water constant, dimensionless

i = infiltration velocity, feet per hour

k = reduction coefficient, hours^{-1}

For a 75 percent reduction in phosphorus:

$e^{-kt} = .25$ (25 percent phosphorus remaining)

$-kt = \text{Ln } .25$

$-kt = -1.386$

$kxv = 1.386i$

$$x = \frac{1.386i}{kv}$$

From the CH_2M Hill study of existing percolation pond performance at the sugar cane mill, a k value of 0.0065 was reported. The EPA recommends k = 0.0020 for neutral pH soils. Given the variability of k, its value should be computed for specific site conditions. For example, for 75 percent phosphorus removal:

if k = 0.0065, x = 117 ft

if k = 0.0020, x = 382 ft

Calculations for 50 percent phosphorus removal and 25 percent phosphorus removal result in narrower levee widths. For 50 percent phosphorus removal:

if k = 0.0065, x = 60 ft

if k = 0.0020, x = 190 ft

For 25 percent phosphorus removal:

if $k = 0.0065$, $x = 25$ ft

if $k = 0.0020$, $x = 80$ ft

Calculation of levee length is based on flow rate through the levee and varies with levee width. Levee lengths can be calculated using the following formula:[10]

$$Q = [(H^2 - h^2) * P * K]/2x \quad (2)$$

where
Q = outflow, cubic feet per day
H = head in pond, feet
h = head in perimeter ditch, feet
P = perimeter of pond or levee length, feet
K = coefficient, dimensionless
x = levee width, feet

Site specific soils information is needed to determine the head required to cause flow through wide levees. For this evaluation, the value of the coefficient K used by CH_2M Hill was considered typical for the EAA.

Based on a reduction coefficient of 0.0065 and a wastewater discharge rate of 4.8 mgd, CH_2M Hill estimated the capital costs for percolation ponds at the Clewiston test site to be $870,000 and $3,679,000 for levee widths of 150 feet and 300 feet, respectively, in 1989 dollars.

Basis of Evaluation

It is theoretically possible to achieve very low effluent TP concentrations using percolation ponds, as long as sufficient levee width can be provided. An analysis was performed using Equation 1 above to test the sensitivity of levee width to incremental changes in effluent TP concentration below 0.05 mg/l. A reduction coefficient of 0.0020 in Equation 1, as recommended by the EPA for neutral pH soils, was used. The factor of 0.0065 derived by CH_2M Hill for percolation ponds at the Clewiston mill is probably high for the EAA as a whole because Clewiston is located in the northwestern portion of the EAA and benefits from a sandy soil not common to most of the EAA. The results of the sensitivity analysis showed a design TP effluent concentration of 0.02 mg/l, with a required levee width of 561 feet, to provide the best balance of treatment performance, levee construction, and land area requirements. Somewhat lower effluent concentrations could possibly be achieved, but land area requirements and construction costs would increase substantially.

Using the information presented on Figure 2-1 in Chapter 2 for an effluent TP concentration of 0.02 mg/l, a treatment capacity of 900 mgd is required at the basin scale to achieve 75 percent TP reduction on a mass basis. Treatment capacities of 400 and 200 mgd are required at the basin scale to achieve 50 and 25 percent TP reduction, respectively. Proportionally less treatment capacity is required at the smaller scales of application for all TP removal levels. Required levee lengths to accommodate the design flows for the various phosphorus removal levels at each scale of application were computed using Equation 2 above. In most cases, land area requirements were not controlled by required levee length, but rather by the excavated area needed to furnish sufficient soil for construction of the levees.

Design flows, required levee lengths, total land area requirements, and estimated capital costs for implementation of percolation ponds at the various scales of application in the EAA are presented in Table 3-4. Capital costs were prepared using cost factors consistent with those used in the CH_2M Hill study and those used by Burns & McDonnell in the conceptual design of the STAs. All capital costs were adjusted to August 1992 dollars.

Levees were assumed to be 7 feet high. Each mile of levee was estimated to contain 370,000 cubic yards of soil material. At $3.25 per cubic yard for levee construction, including pond excavation, the base construction cost per mile of levee was estimated to be about $1.2 million. Additional costs were added to this amount to account for land acquisition, pumping stations, site development, and engineering design. The sum of these costs is reflected in the capital cost totals presented in Table 3-4.

Evaluation Results

The evaluation ratings for percolation ponds are presented in Exhibit 3-4. The technology is rated high for the point source scale of application, where lower volume, higher strength process wastewaters require treatment. The technology received substantially lower ratings for treatment of EAA drainage water at all other scales of application. The land area requirements and capital costs for large-scale facilities are prohibitive.

Discussion of Evaluation Results

Percolation ponds, when properly designed, have significant potential for reducing phosphorus loads. The technology was rated high at all levels of phosphorus reduction. Slightly lower ratings were given at the 75 percent level due to the lack of data documenting sustained performance at very low phosphorus concentrations. Construction of percolation ponds at point sources by 1997 should not be difficult provided geohydrologic conditions are known and determined to be suitable for such facilities. However, implementation schedule at the other scales was given a lower rating due to the amount of land acquisition and magnitude of construction involved.

Construction of percolation ponds is not expected to impact hydroperiod adversely and may actually result in an overall improvement due to the dampening of peak flows. There should be no significant changes to the operational plan for the Central and South Florida Flood Control Project.

Table 3-4 Basis of Evaluation for Percolation Ponds

Parameter	Scale of application							
	Basin		Subbasin		Farm		Point source	
	Scale unit	Total EAA	Scale unit	Total EAA	Scale unit	Total EAA	Scale unit	Total EAA
Design flow, mgd								
25 percent P removal	200	800	20	800	3	550	5	35
50 percent P removal	400	1,600	40	1,600	6	10,481	10	70
75 percent P removal	900	3,600	90	3,600	15	262,600	15	105
Levee length, miles								
25 percent P removal	950	800	95	3,800	14	2,420	24	168
50 percent P removal	1,900	1,600	190	7,600	28	4,800	48	336
75 percent P removal	4,280	3,600	428	17,120	70	12,110	70	490
Land area, acres								
25 percent P removal	80,000	320,000	8,000	320,000	1,600	287,600	2,000	14,000
50 percent P removal	160,000	640,000	16,000	640,000	2,400	415,200	4,000	28,000
75 percent P removal	360,000	1,440,000	36,000	1,440,000	6,000	1,038,000	6,000	42,000
Capital cost,[a] million dollars								
25 percent P removal	1,871	7,484	187	7,484	28	4,844	49	343
50 percent P removal	3,744	14,976	375	14,976	56	9,688	95	665
75 percent P removal	8,433	33,732	843	33,732	140	24,220	140	980

[a] 1992 dollars.

Exhibit 3-4 Phase I Evaluation Ratings for Percolation Ponds

Criterion	Criterion weighting[a]	Scale of application/level of phosphorus reduction[b]											
		Drainage basin			Subbasin			Individual farm			Point source		
		25	50	75	25	50	75	25	50	75	25	50	75
Phosphorus removal capability	3	9/27	7/21	5/15	9/27	7/21	5/15	9/27	7/21	5/15	10/30	9/27	7/21
Implementation schedule	2	6/12	4/8	2/4	6/12	4/8	2/4	4/8	3/6	2/4	9/18	9/18	9/18
Hydroperiod impact	2	6/12	7/14	8/16	6/12	7/14	8/16	6/12	7/14	8/16	6/12	6/12	6/12
Impact on C&SF Project	2	6/12	6/12	6/12	6/12	6/12	6/12	8/16	8/16	8/16	8/16	8/16	8/16
Permitting requirements	2	6/12	6/12	6/12	6/12	6/12	6/12	7/14	7/14	7/14	8/16	8/16	8/16
Previous application of technology	2	2/4	2/4	2/4	2/4	2/4	2/4	2/4	2/4	2/4	8/16	6/12	4/8
Capital cost	1	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1
O&M requirements	1	7/7	7/7	7/7	7/7	7/7	7/7	7/7	7/7	7/7	7/7	7/7	7/7
Economic impacts	1	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1
Total		88	80	72	88	80	72	90	84	78	117	110	100

[a] Criteria directly related to satisfying provisions of SWIM Plan receive a weighting of 2 or 3; all other criteria receive a weighting of 1.
[b] Phosphorus reduction levels of 25, 50 and 75 percent of the influent phosphorus estimated for each scale of application.

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Permits related to initial construction of improvements will be required at all scales of application. Some difficulty in obtaining permits is anticipated due to the site-specific design of percolation ponds. It also is anticipated that operation permits will require monitoring to assess and document long-term percolation and phosphorus reduction rates. The overall operating requirements of percolation ponds are expected to be relatively low.

The use of percolation ponds for phosphorus removal at a point source level of application has been pilot tested in the field. However, data from the pilot testing have not been reported. Therefore, the performance of the pilot treatment unit in removing phosphorus is unknown. The technology has not been tested at any scale on agricultural drainage water from the EAA.

Land area requirements for percolation ponds are significant, much higher than the base case wetland system for treatment of agricultural drainage water. Land area requirements at the point source scale are potentially manageable, particularly if process wastewater flows can be recycled as proposed in the CH_2M Hill study. Capital costs for percolation pond treatment facilities are expected to be significantly higher than for the base case wetland system, owing primarily to the large land areas and magnitude of levee construction involved.

In summary, percolation ponds have the potential to remove phosphorus in agricultural drainage water to the 50 ppb level. However, they seem best suited for the point source level of application as proposed in the CH_2M Hill study. The geohydrologic conditions of the site must be known and understood for proper design, and further research is necessary to estimate the length of time soils can be expected to provide the required level of treatment.

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DEEP WELL INJECTION

Deep well injection is recognized as an effective method for the controlled disposal of treated wastewater from municipal, industrial, and agricultural sources. Deep well injection involves pumping wastewater into deep subsurface geologic zones where the wastewater can be stored for extended periods of time. Although not a treatment process, deep well injection has been proposed as an alternative technology for reducing phosphorus discharges from the EAA. This technology is not proprietary and has been used successfully in South Florida for about 25 years.

Overview of Technology

The deep well injection technology is based on the assumption that liquid wastes can be pumped safely into certain geologic units beneath the land surface with minimal risk of contamination of overlying groundwater sources of drinking water. The selected geologic zone typically must:

- Be physically separated from sources of potable water by sound confining layers;
- Not be classified as a current or future potential potable water supply;
- Contain natural water of a quality that makes it unsuitable as a potable water supply; and
- Have sufficient extent, thickness, and lithologic and hydraulic characteristics to adequately receive the waste.

Deep wells for the disposal of wastewaters are classified by the Florida DER as Class I injection wells. Approximately 80 Class I wells are in use in Florida, with 14 wells operating successfully in Palm Beach County. The injection zone of choice in South Florida is the Oldsmar Limestone, or "boulder zone," located about 2,700 to 3,300 feet below land surface within the Lower Floridan Aquifer. Operating pressures for injection wells range from 35 to 50 psi, with a maximum allowable flow velocity of 8 fps. Deep well injection systems may be installed either as single-well or as multiple-well systems. This allows the technology to be applied over a wide range of flows.

A deep well injection system typically consists of: (1) storage at the ground surface in tanks or lagoons; (2) pumps and associated equipment; (3) wells for injection of the wastes into the designated geologic zone; and (4) water quality monitoring wells with associated sampling equipment and instrumentation to monitor system performance and to detect leaks which could result in contamination of overlying aquifers.

Basis of Evaluation

Because wide ranges of flows can be accommodated with multiple well systems, deep well injection technology can be considered for all scales of application in the EAA. Because the technology is a disposal method rather than a treatment method requiring surface discharge, the number

Table 3-5 Basis of Evaluation for Deep Injection Wells

Parameter	Scale of application							
	Basin		Subbasin		Farm		Point source	
	Scale unit	Total EAA	Scale unit	Total EAA	Scale unit	Total EAA	Scale unit	Total EAA
Well capacity, mgd								
25 percent P removal	200	800	20	800	3	567	10	70
50 percent P removal	300	1,200	30	1,200	5	848	12	84
75 percent P removal	500	2,000	50	2,000	8	1,418	15	105
Number (and size) of wells								
25 percent P removal	14 (24")	56 (24")	1 (24") 1 (14")	40 (24") 40 (14")	1 (14")	173 (14")	1 (24")	7 (24")
50 percent P removal	20 (24")	80 (24")	2 (24")	80 (24")	1 (14")	173 (14")	1 (24")	7 (24")
75 percent P removal	34 (24")	136 (24")	3 (24") 1 (14")	120 (24") 40 (14")	1 (24")	173 (24")	1 (24")	7 (24")
Land area, acres								
25 percent P removal	144	576	34	1,360	18	3,114	18	126
50 percent P removal	173	692	34	1,360	18	3,114	18	126
75 percent P removal	281	1,124	52	2,080	18	3,114	18	126
Capital cost,[a] million dollars								
25 percent P removal	69	276	8.4	338	3.5	605	5.0	35
50 percent P removal	99	395	10.0	397	3.5	605	5.0	35
75 percent P removal	168	671	18.3	732	5.0	858	5.0	35

[a] 1992 dollars.

of wells required is strictly a function of flow rate and is not affected by variations in phosphorus loadings.

In a report for U.S. Sugar Corporation, CH_2M Hill estimated the construction cost of a 14-inch-diameter injection well system, capable of disposing of 4.8 mgd, to be about \$2.8 million. A 24-inch-diameter injection well system, capable of disposing of 15 mgd, was estimated to have a construction cost of \$3.95 million in 1989 dollars.[11] For the purpose of developing capital cost estimates for the various scales of application in the EAA, it was assumed that 14- or 24-inch wells would be used. Multiple well systems were assumed when needed to accommodate flows in excess of the 15-mgd capacity of a 24-inch well. In this evaluation, the total capital cost of 14-inch and 24-inch wells, including land and engineering, was estimated to be \$3.5 million and \$5.0 million, respectively, in 1992 dollars.

The Florida DER considers permit applications for each injection well system based on site-specific data gathered by the permit applicant as required by the Underground Injection Control regulations (17-28, FAC). Since specific well locations have not been selected, it was assumed conservatively that all injection wells would be located 500 feet from all other injection wells and all site boundaries. It also was assumed that an appropriate geologic zone such as the Oldsmar Limestone is present throughout the EAA at about 3,000 feet below land surface.

Based on the information presented on Figure 2-1 in Chapter 2, total well capacity of 500 mgd would be required to achieve 75 percent phosphorus removal at the basin scale. Well capacities of 300 mgd and 200 mgd would be required to achieve 50 and 25 percent phosphorus removals, respectively, at the basin scale. At the smaller scales of application, proportionally less well capacity is required. The total well capacity and number of wells required, the estimated land requirements, and the capital cost estimates for deep well injection at the four scales of application in the EAA are presented in Table 3-5.

Evaluation Results

The evaluation ratings given to deep well injection at the various scales of application and levels of phosphorus reduction are presented in Exhibit 3-5. The technology received high ratings at the point source scale, but received considerably lower ratings at the basin, subbasin, and farm scales. This is reasonable given that point sources typically involve lower volume, higher strength wastewaters with reduced levels of flow variability compared with discharges of drainage water from agricultural fields.

Deep well injection rates high for phosphorus removal capacity since the water containing the phosphorus is disposed of underground and never recovered. With 80 systems in operation in Florida, deep well injection also receives relatively high ratings for previous application of technology. Other advantages include relatively low operation and maintenance requirements and minor land area requirements compared with many of the other technologies.

Major disadvantages of deep well injection are permitting, implementation schedule, and impact on hydroperiod. Permitting large-scale deep well injection systems is likely to take several

Exhibit 3-5 Phase I Evaluation Ratings for Deep Well Injection

Criterion	Criterion weighting[a]	Scale of application/level of phosphorus reduction[b]											
		Drainage basin			Subbasin			Individual farm			Point source		
		25	50	75	25	50	75	25	50	75	25	50	75
Phosphorus removal capability	3	10/30	8/24	6/18	10/30	9/27	8/24	10/30	10/30	9/27	10/30	10/30	10/30
Implementation schedule	2	1/2	1/2	1/2	1/2	1/2	1/2	2/4	2/4	2/4	9/18	9/18	9/18
Hydroperiod impact	2	3/6	2/4	1/2	3/6	2/4	1/2	3/6	2/4	1/2	4/8	3/6	2/4
Impact on C&SF Project	2	1/2	1/2	1/2	2/4	2/4	2/4	4/8	4/8	4/8	8/16	8/16	8/16
Permitting requirements	2	3/6	3/6	3/6	3/6	3/6	3/6	3/6	3/6	3/6	6/12	6/12	6/12
Previous application of technology	2	5/10	5/10	5/10	8/16	8/16	8/16	9/18	9/18	9/18	9/18	9/18	9/18
Capital cost	1	5/5	4/4	3/3	4/4	5/5	3/3	3/3	4/4	3/3	4/4	5/5	5/5
O&M requirements	1	8/8	8/8	8/8	7/7	7/7	7/7	6/6	6/6	6/6	8/8	8/8	8/8
Economic impacts	1	9/9	9/9	8/8	8/8	8/8	8/8	8/8	8/8	8/8	10/10	10/10	10/10
Total		78	69	59	83	79	72	89	88	82	124	123	121

[a] Criteria directly related to satisfying provisions of SWIM Plan receive a weighting of 2 or 3; all other criteria receive a weighting of 1.
[b] Phosphorus reduction levels of 25, 50 and 75 percent of the influent phosphorus estimated for each scale of application.

years to complete, even if subsurface conditions are found to be favorable. Given that there are a limited number of drill rigs available with the capability to construct these deep wells and that construction of a well can take several months to complete, it is doubtful that a significant number of deep wells can be in place by 1997. Also, since water would be physically removed from the EAA and would not be available to the Everglades, deep well injection would have an adverse impact on hydroperiod at all scales of application, increasing in significance at larger scales.

Discussion of Evaluation Results

Deep well injection is a proven technology requiring minimal utilization of land resources. However, the difficulty in obtaining permits and the loss of water resources make this technology less attractive for implementation in the EAA.

The permitting of Class I underground injection wells in Florida is a long and arduous process. A series of permits must be obtained from the Florida DER. These permits include the following:

- Class I Exploratory Well Construction and Testing Permit
- Class I Test/Injection Well Construction and Testing Permit
- Class I Injection Well Operating Permit
- Class I Well Plugging and Abandonment Permit

The Exploratory Well Construction and Testing Permit allows the applicant to construct an exploratory well that is drilled for the specific purpose of obtaining sufficient information to determine the feasibility of underground injection at the proposed site. The Test/Injection Well Construction and Testing Permit is granted to an applicant to construct an injection well for long-term testing. Testing of the injection zone is necessary to demonstrate the zone's capacity for receiving the injected fluid by evaluating hydraulic characteristics, lithology, etc. The Injection Well Operating Permit establishes operating, monitoring, testing, and reporting parameters. Applicants for Underground Injection Control permits also must submit a plan for plugging and abandonment of the wells, which may include post-closure care and monitoring. The DER will require permittees to maintain financial resources in the form of performance bonds or other equivalent form of financial assurance to close, plug, and abandon the underground injection operation. The DER also may require the permittee to maintain financial assurance to cover any post-closure monitoring and any corrective action resulting from the monitoring. Current experience indicates that simple systems involving single wells take up to 2 years to satisfy permitting requirements. Larger, more complex systems may require longer permitting periods.

While this technology is proven, reliable, generally protective of human health and the environment and requires minimal land utilization, its benefits to the EAA are questionable. The loss of water to the Everglades would be a serious adverse impact resulting from deep well injection. Furthermore, the cost of the technology is high and probably cannot be justified except for disposal of selected point source discharges that are low in volume and high in phosphorus concentration.

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AQUIFER STORAGE AND RECOVERY

Aquifer storage and recovery (ASR) has been established as a successful and effective technology for the storage and subsequent retrieval of water when geologic and hydrogeologic conditions are favorable. The ASR technology uses an engineered system to inject water above or into subsurface sources of potable water supplies, either by gravity flow or pumping. About 10,000 ASR wells reportedly exist in Florida.[14] The majority of these wells are associated with air conditioning return flow, swimming pool drainage, stormwater runoff control, and lake level control. The technology is in the public domain and, therefore, is not subject to patent restrictions. ASR has been proposed as an alternative technology for reducing phosphorus discharges from the EAA.

Overview of Technology

The ASR technology is based on the premise that water may be placed in a subsurface aquifer for storage and then recovered later for beneficial use. The subsurface geologic zone typically selected as the storage zone has high transmissivity and storage characteristics. The technology has been used to manage a wide range of flows in what often is a closed-loop system. Water withdrawn from an aquifer for beneficial use is returned to the same hydrogeologic unit.

The Florida DER classifies wells for ASR as Class V wells. These wells may operate at pressures varying from gravity flow to 50 psi. DER regulations (17-28, FAC) limit the velocity within wells to 8 feet per second (fps). ASR systems may operate over a wide range of flow rates by installing multiple wells and pumps. Depending on variability in flow rates, some wells can be placed in standby mode while other wells are operational. An ASR system typically consists of: (1) storage at the ground surface in tanks or lagoons; (2) pumps and associated equipment; (3) wells for injection and recovery of water from the aquifer; and (4) water quality monitoring wells with associated sampling equipment and instrumentation to monitor system performance and to check for potential contamination of the aquifer.

A large-scale demonstration project was performed to evaluate this technology for the protection of water quality in Lake Okeechobee.[11,14] Single well systems using 14-inch and 24-inch wells were evaluated. At 8 fps, the 14- and 24-inch wells would be capable of conveying about 5 and 15 mgd, respectively. The ASR system constructed for the Lake Okeechobee project was installed to the Upper Floridan Aquifer located 1,300 to 1,700 feet below land surface. The results of the Okeechobee project indicated that the application of ASR resulted in a removal of about 30 percent of the total phosphorus present in the injected water. Modeling and laboratory analyses conducted by CH_2M Hill as part of the Lake Okeechobee study led to the conclusion that adsorption of phosphorus by limestone was occurring and that the phosphorus reduction observed was not solely the result of dilution with groundwater.

At the basin scale in the EAA, ASR technology could be used to store stormwater flows for subsequent use as water supply for downstream users or for discharge to the Everglades during drought conditions. ASR could prove to be a viable means of managing water resources in the region and is currently being considered as a component of the District's Lower East Coast Water Supply Plan. However, if used in this manner, phosphorus reduction would be limited.

At the subbasin and farm scales, ASR could be used to reduce irrigation pumping from District canals as well as drainage discharges to District canals. This would make more high quality water from Lake Okeechobee available for downstream water supply. At the farm scale, use of ASR takes on a role similar to that of a Best Management Practice (BMP) for controlling stormwater discharges. Phosphorus loads discharged from farms in the EAA are generally proportional to the volume of drainage water pumped. Therefore, if ASR could reduce the volume of water pumped off-farm over and above the reduction realized from implementation of BMPs, then phosphorus load reductions greater than those achieved in the Lake Okeechobee demonstration project are possible.

Basis of Evaluation

Since wide ranges of flows can be accommodated by ASR by adding additional wells, this technology can be considered for all scales of application in the EAA. Without site-specific data on geologic and hydrogeologic conditions, it was assumed that the 30 percent phosphorus reduction level achieved by the Lake Okeechobee project can also be attained in the EAA. However, in consideration of anticipated bypasses for peak wet weather conditions, the best possible phosphorus reduction attainable for this technology, without reductions in the volume of drainage water pumped off farms, is only about 25 percent. For this reason, the ASR technology is considered only at the 25 percent phosphorus reduction level at the basin scale.

At the subbasin and farm scale, it was assumed that ASR could effect a 25 percent reduction in the volume of drainage water pumped off-farm over and above that achievable with BMPs. At these scales, ASR was evaluated at both the 25 and 50 percent phosphorus reduction levels.

CH_2M Hill prepared cost estimates for single well ASR systems using 14- and 24-inch wells.[14] Construction cost estimates were $1.3 million and $1.6 million, respectively, in 1989 dollars. For the purpose of developing capital cost estimates for the various scales of application in the EAA, it was assumed that 14- or 24-inch wells would be used. Multiple well systems were assumed when needed to accommodate flows in excess of the 15-mgd capacity of a 24-inch well. For this evaluation, the total capital cost of 14- and 24-inch wells, including land and engineering, was estimated to be $1.6 million and $2.0 million, respectively, in 1992 dollars.

The Florida DER considers permit applications for each injection well system based on site-specific data gathered by the permit applicant as required by the Underground Injection Control regulations (17-28, FAC). Since specific well locations have not been selected, it was assumed that all ASR wells would be located 500 feet from all other ASR wells and all site boundaries. It also was assumed that the wells would be installed to the same depth that was used for the Lake Okeechobee project and that hydrogeologic units with appropriate characteristics for ASR are present throughout the EAA. Generalized geologic atlas data for Florida does not document categorically the presence or absence of appropriate aquifer characteristics.

To achieve 25 percent removal of TP at the basin scale over the entire EAA, assuming a 30 percent reduction in phosphorus concentration in the limestone aquifer, virtually all of the drainage water from the EAA would have to be pumped into the ASR system. This is clearly not feasible. Therefore, for the purposes of this evaluation, a design flow of 500 mgd was assumed for basin scale ASR facilities. While this quantity of flow being treated in the ASR system will probably not result in 25 percent TP removal over the entire EAA, removal of 10 percent may be achievable.

Design flows of 50, 8, and 15 mgd were assumed for the subbasin, farm, and point source scales. These design flow rates are proportional to the 500 mgd used at the basin scale. The phosphorus reduction achievable with implementation of ASR at these scales of application is highly dependent on how much of the stormwater stored in the aquifer can be reused on-farm for irrigation and other beneficial purposes to reduce drainage discharges. The number of wells required, the estimated land area requirements, and estimates of capital cost for aquifer storage and recovery at the four scales of application in the EAA are presented in Table 3-6.

Table 3-6 Basis of Evaluation for Aquifer Storage and Recovery

Scale of application	Design flow, mgd	Number (and size) of wells required		Land area, acres		Capital cost,[a] million dollars	
		Scale unit	Total EAA	Scale unit	Total EAA	Scale unit	Total EAA
Basin	500	34 (24")	136 (24")	281	1,124	66	264
Subbasin	50	3 (24") 1 (14")	120 (24") 40 (14")	52	2,080	7.5	299
Farm	8	1 (24")	173 (24")	18	3,114	2.0	341
Point source	15	1 (24")	7 (24")	18	126	2.0	14

[a] 1992 dollars.

Evaluation Results

The evaluation ratings given to ASR at the various scales of application are presented in Exhibit 3-6. The ASR technology received its highest ratings at the point source scale and its lowest ratings at the basin scale.

Probably the most important benefit of the ASR technology at the basin scale is its potential to make more water available for water supply and to improve hydroperiod in the Everglades. During wet weather conditions, runoff would be pumped below ground for storage. During periodic dry weather conditions, water could be withdrawn for drinking water supply or for discharge to the Everglades. It should be noted, however, that all water pumped into the aquifer may not be available for withdrawal at all times. Withdrawal capacity from the aquifer at any point in time is a function of many variables, including past hydrologic conditions in the recharge zones of the aquifer.

At the subbasin, farm, and point source scales, ASR could provide the additional benefit of increased phosphorus reduction if stored runoff can be reused for irrigation purposes and drainage

Exhibit 3-6 Phase I Evaluation Ratings for Aquifer Storage and Recovery

Criterion	Criterion weighting[a]	Scale of application/level of phosphorus reduction[b]											
		Drainage basin			Subbasin			Individual farm			Point source		
		25	50	75	25	50	75	25	50	75	25	50	75
Phosphorus removal capability	3	2/6	N/A[c]	N/A	4/12	2/6	N/A	6/18	4/12	N/A	4/12	2/6	N/A
Implementation schedule	2	1/2			2/4	2/4		3/6	3/6		5/10	5/10	
Hydroperiod impact	2	9/18			8/16	8/16		7/14	7/14		5/10	5/10	
Impact on C&SF Project	2	9/18			9/18	9/18		9/18	9/18		9/18	9/18	
Permitting requirements	2	1/2			1/2	1/2		1/2	1/2		1/2	1/2	
Previous application of technology	2	3/6			3/6	3/6		3/6	3/6		3/6	3/6	
Capital cost	1	5/5			4/4	5/5		5/5	6/6		7/7	8/8	
O&M requirements	1	8/8			8/8	8/8		5/5	5/5		8/8	8/8	
Economic impacts	1	8/8			8/8	8/8		8/8	8/8		10/10	10/10	
Total'		73			78	73		82	77		83	78	

[a] Criteria directly related to satisfying provisions of SWIM Plan receive a weighting of 2 or 3; all other criteria receive a weighting of 1.
[b] Phosphorus reduction levels of 25, 50 and 75 percent of the influent phosphorus estimated for each scale of application.
[c] Aquifer storage and recovery not evaluated at these phosphorus reduction levels.

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volumes pumped off-site are reduced. The reduction in drainage water pumped will vary on a case-by-case basis as will the level of phosphorus reduction achieved.

One of the most important drawbacks of the ASR technology is its permittability. Though ASR is used widely in Florida, its application for phosphorus reduction in the EAA is a modification of the technology that has not been widely implemented previously. Typically, water injected through a Class V well must meet drinking water standards. If it does not, extensive pretreatment or waivers from existing regulations are required. Since implementation of this technology in the EAA has not been demonstrated, it is expected that the permitting process for ASR wells will be even more complex and lengthy than normal. It is doubtful that a sufficient number of ASR wells could be permitted by 1997, under existing FDER regulations, for the technology to play a significant role in meeting the requirements of the SWIM Plan.

<u>Discussion of Evaluation Results</u>

Though ASR is used throughout Florida, the modification of the technology to include surface discharge has not been proven to be protective of human health and the environment. To construct the ASR demonstration system for the Lake Okeechobee project, six different permits were required from the Florida DER, the U.S. Army Corps of Engineers, and the U.S. Environmental Protection Agency (EPA). The permits included an Aquifer Exemption from the EPA, which was the first ever issued, to allow untreated surface water to be injected into the aquifer. In addition, a Water Quality Exemption from DER is required for injection into an aquifer if the water fails to meet water quality concentration guidelines for drinking water standards. If no standards or guidelines exist for a constituent of concern, then the applicant must request that DER establish a project-specific standard for the parameter. Pretreatment may be required prior to injection to insure that the injected fluid will not violate water quality standards at the point of discharge. Other DER permits include:

- Construction/Clearance Permit for Class V Wells
- Operating Permit for Class V Wells
- Plugging and Abandonment Permit for Class V Wells

This elaborate permitting process requires extensive preliminary studies and testing prior to construction; stringent construction standards and inspections; and a strict testing and monitoring program during operation. Applicants for underground injection control permits also must submit a plan for plugging and abandonment of the wells, which may include post-closure care and monitoring.

Recently, discussions have been initiated between the USEPA, FDER, and the Water Management Districts in Florida to explore how the permitting process for ASR systems can be facilitated. It may also be possible for dedicated on-farm ASR systems to receive agricultural stormwater exemptions. However, regulatory agencies are not willing to render definitive opinions on the future of ASR permitting at this time. ASR has potential for becoming a significant component of overall water resources management in the EAA and South Florida. However, in the strict context of being able to remove significant amounts of phosphorus from EAA runoff by 1997 to satisfy the requirements of the SWIM Plan, its applicability is questionable.

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WATER QUALITY/SUPPLY DIVERSION PLAN

The Water Quality/Supply Diversion Plan (WQSD Plan) has been developed as an alternative to address water quality problems in the Water Conservation Areas (WCAs) and Everglades National Park (ENP) along with water supply problems in the coastal urban areas of Palm Beach, Broward, Dade, and Monroe Counties. The WQSD Plan proposes to reduce phosphorus loadings to the WCAs by diverting a portion of the runoff from the EAA to the coastal areas for recharging the surficial aquifer and for meeting other demands for water supply. This runoff currently is pumped into the WCAs. To offset the reduced flows to the WCAs, the WQSD Plan recommends reducing or eliminating the current releases of water from the WCAs to the Lower East Coast (LEC). A schematic diagram illustrating the current flow paths of water through the EAA and WCAs to the ENP and LEC is presented on Figure 3-8.

Overview of Technology

The management plan for surface water discharges from the EAA has changed dramatically over the past decade due to concern over nutrient impacts on surface water bodies such as Lake Okeechobee, the WCAs, and the coastal estuaries. The first change in the management of water discharged from the EAA was to essentially cease backpumping from the EAA into Lake Okeechobee to reduce the nutrient loads to the lake. In addition, management practices for the dairy industries along the lake are being altered to reduce agricultural loads to the lake. The SWIM Plan for the EAA calls for the treatment of the agricultural runoff that is discharged to the WCAs. The WQSD is designed to significantly reduce the need for treatment of EAA discharges by diverting surface water containing unacceptable levels of phosphorus to the coastal drainage system.

A basic assumption of the WQSD Plan is that the water quality of the runoff from the EAA generally meets or exceeds the water quality requirements for sources of potable water. Therefore, the Plan assumes that directing EAA runoff to the LEC should not present a water quality problem to the LEC area. From a water supply standpoint, this may be a valid assumption. However, from the standpoint of nutrient loadings and discharges of other constituents to the estuarine systems along the LEC, diversion of EAA water may, in fact, create adverse water quality impacts.

The flow of water through the EAA and WCAs to the ENP and LEC occurs in canals that are part of the Central and South Florida Flood Control Project. To implement the WQSD Plan, the following improvements and modifications would be needed to the Central and South Florida Flood Control Project:

1. Construction of three new water control structures along the Hillsboro, North New River, and Miami Canals, each located south of the Cross and Bolles Canals, to divide the EAA into two (north and south) basins. The location of these control structures are illustrated graphically on Figure 3-9.

2. Improvements to the Cross and Bolles Canals to provide primary collection from the northern basin of the EAA westward to the S-5A pumping station complex.

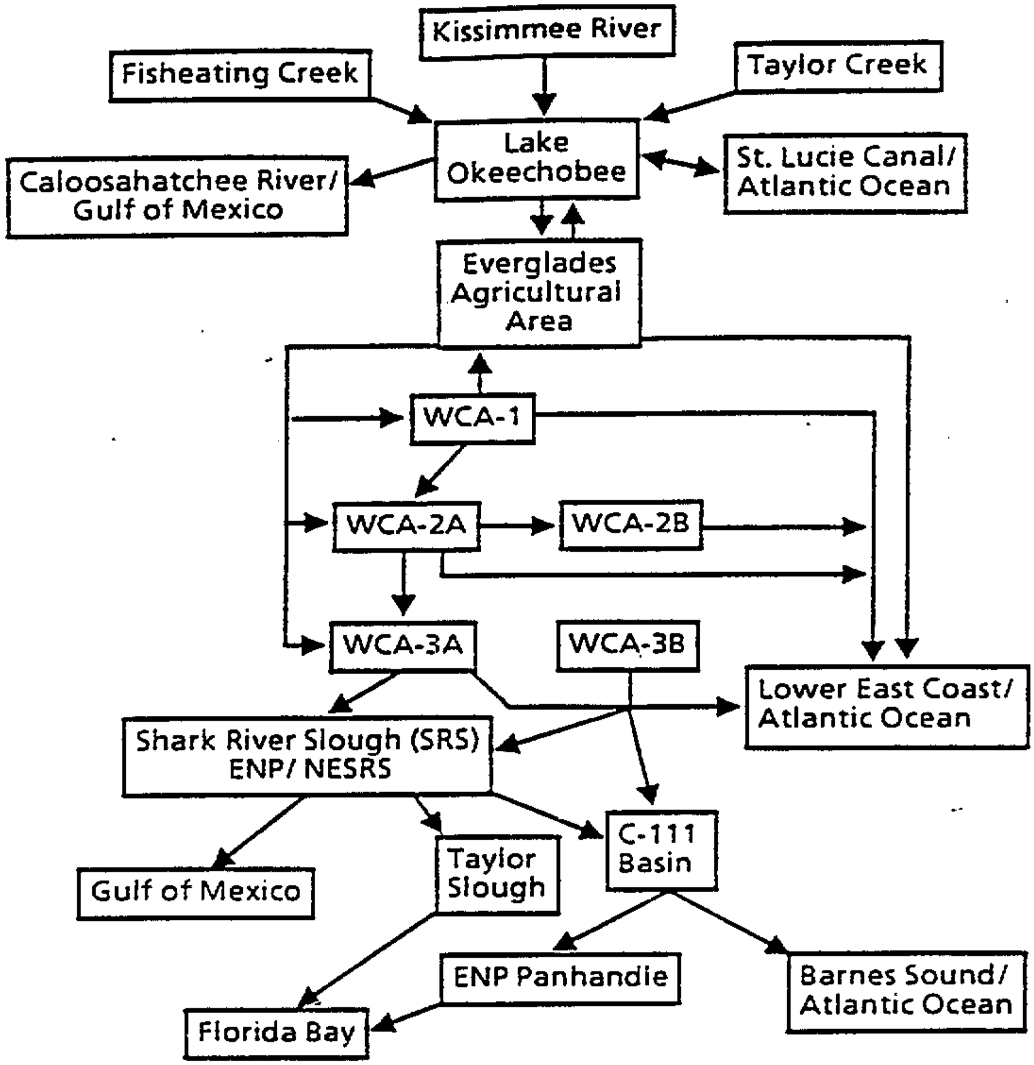

Figure 3-8
Schematic Diagram of Water Movement In the South Florida Water Management District

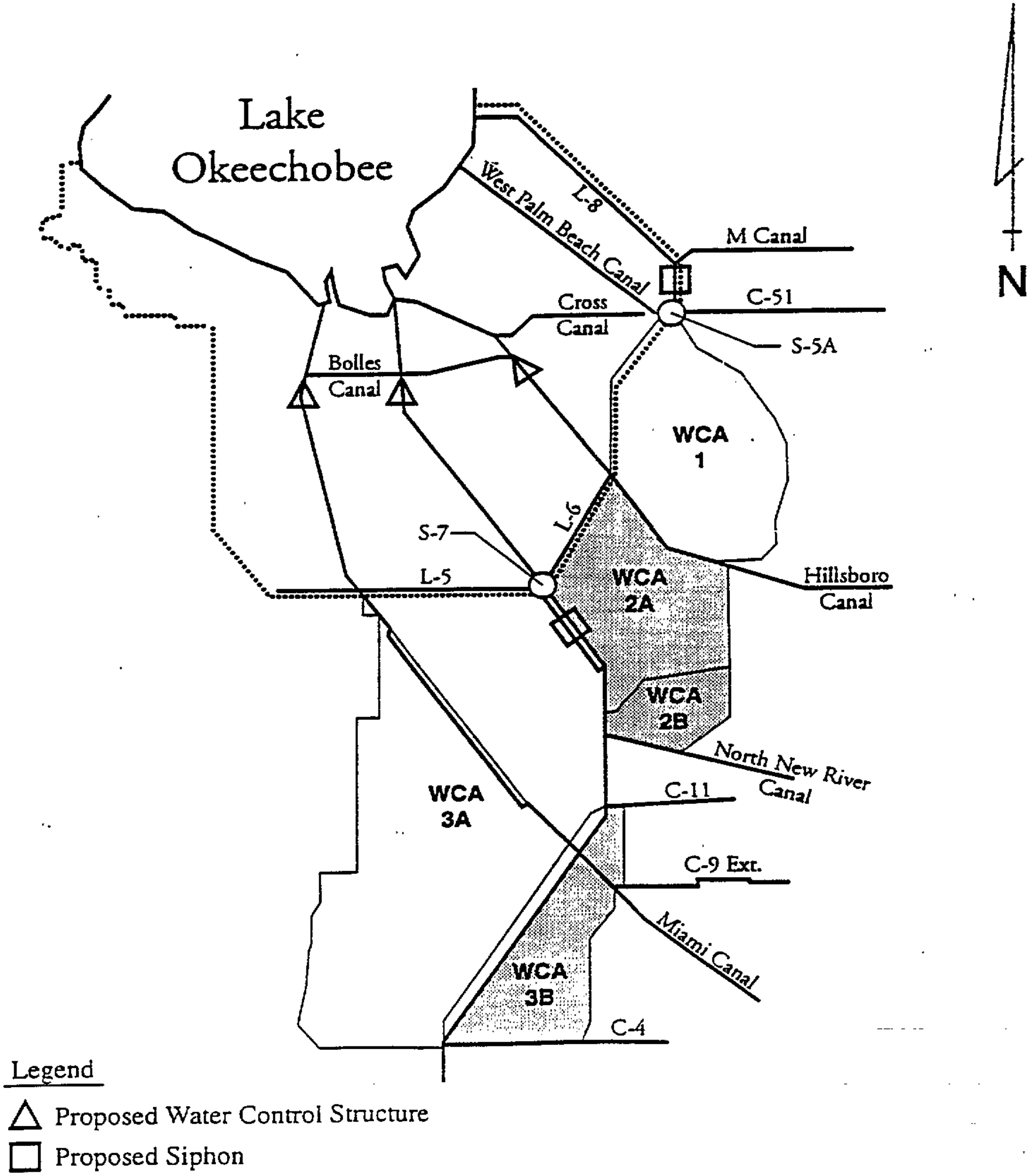

Figure 3-9
Location Map for Water Quality/Supply Diversion Plan

3. Relocation of the L-8 Canal west of the current L-8 Canal and construction of a siphon and pumping station to route EAA runoff eastward under the proposed L-8 Canal (via the siphon) to the old L-8 Canal. According to the Plan, runoff would flow northward to Palm Beach County through the M Canal and into the West Palm Beach Water Catchment Area. The Plan also indicates that water from the Catchment Area would be routed southward to the Lake Worth Drainage District and northward to the C-18 Canal and Loxahatchee River. This may require modifications to the West Palm Beach Catchment Area water control system.

4. Improvements to the North New River Canal to convey runoff from the southern portion of the EAA to Broward County. Levees would be constructed along both sides of the improved canal to isolate the EAA runoff from the WCAs. Siphons would be constructed to pass water under the North New River Canal from WCA 2A to WCA 3A.

5. Reservoirs probably would be needed in the EAA to provide temporary storage of peak runoff volumes for later diversion. The size and location of these reservoirs have not been developed at this time.

__Basis of Evaluation__

An evaluation of the WQSD Plan can be made only at the basinwide scale of application. According to the Plan, phosphorus reduction to the WCAs is expected to be approximately 50 percent based on the assumption that 40 to 60 percent of the EAA runoff can be diverted to the LEC. This would appear to be an optimistic assumption given that canals below the WCAs have little, if any, wet weather flow capacity available, and no provision is made in the Plan for storing wet weather flows. It would seem that the amount of water that could be diverted from the EAA, without extensive storage improvements downstream of the EAA, would be limited by the amount of water that is currently withdrawn for water supply purposes by LEC water utilities. Limited data is available regarding past water supply withdrawals from the WCAs. The District is currently investigating the quantity of water withdrawn to allow additional evaluations to be conducted by proponents of the Plan.

The capital cost of the structural improvements and modifications to Central and South Florida Flood Control Project facilities proposed by this Plan, as estimated by Howard L. Searcy Consulting Engineers, is approximately $100 million. However, this cost estimate does not include the cost to construct additional reservoir(s) in the EAA for detention of EAA runoff or any capital improvements which may be needed within the LEC to convey, treat, or store water coming out of the EAA. These additional costs could total as much, if not more, than the capital costs for the diversion improvements themselves.

__Evaluation Results__

The ratings given to the WQSD Plan at the basin scale of application are shown on Exhibit 3-7. The Plan was found to have significant phosphorus reduction capability on an average annual basis, but based on the information provided, cannot achieve 75 percent reduction. Therefore, the

Exhibit 3-7 Phase I Evaluation Ratings for Water Quality Supply/Diversion Plan

Criterion	Criterion weighting[a]	Scale of application/level of phosphorus reduction[b]											
		Drainage basin			Subbasin			Individual farm			Point source		
		25	50	75	25	50	75	25	50	75	25	50	75
Phosphorus removal capability	3	8/24	2/6										
Implementation schedule	2	3/6	3/6										
Hydroperiod impact	2	4/8	4/8										
Impact on C&SF Project	2	2/4	1/2										
Permitting requirements	2	4/8	4/8										
Previous application of technology	2	4/8	2/4										
Capital cost	1	5/5	5/5										
O&M requirements	1	6/6	6/6										
Economic impacts	1	9/9	8/8										
Total		78	53										

[a] Criteria directly related to satisfying provisions of SWIM Plan receive a weighting of 2 or 3; all other criteria receive a weighting of 1.
[b] Phosphorus reduction levels of 25, 50 and 75 percent of the influent phosphorus estimated for each scale of application.

7016EX3-7

Plan was scored only at the 25 percent and 50 percent removal levels. The Plan was scored high at the 25 percent level but was considered only marginally capable of achieving a 50 percent reduction. The Plan does not address reducing phosphorus concentration in undiverted flows or scheduled releases from Lake Okeechobee to the ENP.

Implementation of the WQSD Plan by 1997 is possible--provided a detailed study regarding operation can be made and operational changes are cleared with applicable agencies. Implementation of the WQSD Plan will require both construction and operation permits. Additionally, the Plan will require the cooperation of farmers in managing discharges to the District's canal system. Detention of stormwater runoff on farm for controlled release to the primary canal system will be very important to the successful implementation of the Plan. The anticipated difficulty in receiving permits from the many different agencies affected by the proposed operational changes and the difficulty anticipated in receiving full cooperation by farm owners resulted in a low rating for both implementation schedule and permitting requirements.

The proposed diversion of EAA runoff to the LEC will result in a reduction of flow to the WCAs. To offset this reduction of flow, the WQSD Plan proposes that, if the demand for water by the LEC can be met from the EAA diversion, then the current demands and/or releases of water from Lake Okeechobee and the WCAs to the LEC would no longer be necessary. According to the WQSD Plan, a large portion of the potential deficit in volume could be mitigated by reducing or eliminating the current draft placed on Lake Okeechobee and the WCAs by the LEC. However, no water balance has been performed to demonstrate that the releases from the WCAs approach the volumes of water proposed for diversion. Therefore, this technology rated low with respect to hydroperiod impact.

The WQSD Plan is expected to have significant impacts on the Central and South Florida Flood Control Project. The principal benefit of the WQSD Plan to the LEC is water supply. The Plan gives minimal consideration to flood protection. The Plan reduces the number of normal outlets from the EAA from four (West Palm Beach Canal, Hillsboro Canal, North New River Canal, and Miami Canal) to two (West Palm Beach Canal and North New River Canal). This may affect the existing water supply and flood control facilities within the LEC. If water releases to the Hillsboro Canal from the WCAs are eliminated, this could have a negative impact on the water supply system in the Hillsboro Basin. The WQSD Plan may require further enhancements to improve the water supply to all parts of the LEC. According to the Army Corps of Engineers, the Plan probably will require a reauthorization from the U.S. Congress.

Diversion of EAA runoff has been used previously to reduce nutrient loadings in Lake Okeechobee. The WQSD Plan proposes to divert EAA runoff from the WCAs to the LEC and, as in the past, it is likely that phosphorus reductions will result. However, the increase in nutrient loadings to canals and storage areas of the LEC may require improvements to offset impacts. Due to these issues and the inability of the existing canal system to handle peak storm flows, the WQSD Plan received a low rating with respect to previous application of technology.

The capital cost estimated for the structural improvements and modifications proposed by the WQSD Plan is approximately $100 million, which is lower than the estimated capital cost of the base case alternative. However, the cost estimated for the WQSD Plan did not include cost estimates for storage areas within the EAA to detain runoff when water supply exceeds water demands or transmission capacity. Because the Plan, as currently proposed, does not address storage, the size and cost of storage areas required are not known. Since the storage areas would be used only to store runoff and not to treat it, they could be deeper than the STAs. This would result in less land area being required. Capital cost, therefore, could also be less than the base case wetland alternative. How much less will depend on the magnitude of storage improvements required. If improvements to the LEC canal systems are required to accommodate diverted flows from the EAA, or if water from the EAA must be treated to achieve a higher phosphorus reduction level or to prevent water quality problems in the LEC, the capital cost of the WQSD Plan could be substantially higher than the base case wetland alternative.

The feasibility of the WQSD Plan is also dependent upon a proper operation program. Constant monitoring of water levels throughout the LEC, EAA, WCAs, ENP, and Lake Okeechobee will be necessary. Regulation schedules for Lake Okeechobee and the WCAs will need to be revised and managed. Overall, the WQSD Plan received a somewhat lower rating for the degree of operation and maintenance required than did the base case wetlands alternative.

The WQSD Plan is expected to require less land than the base case wetland alternative which requires approximately 32,000 acres of land for STAs. The storage areas required to store EAA runoff when water supply exceeds demand or when flows are restricted by stages in the LEC canals, would be expected to be less than 32,000 acres since they can be constructed to much greater depths. Actual storage area requirements are dependent on the ability of farmers to detain runoff on the farm for controlled release to the canal system.

Discussion of Evaluation Results

The potential for some phosphorus reduction within the WCAs by diversion of EAA runoff to the LEC is good. However, a detailed study regarding operation will be required to insure that reductions in flow to the WCAs can be offset by similar reductions in withdrawals from the WCAs by the LEC. Due to timing problems as a result of the great variability in EAA discharges and LEC demands for water, large storage area(s) are likely to be required. The need for storage is given little consideration in the Plan, as currently proposed. Releases of water from the storage area(s) could also be restricted when stage in the LEC canals is high, thus increasing the potential for flooding in the EAA.

The estimated capital costs developed by the Plan's proponents are lower than the base case wetland alternative. However, the Plan does not address the cost of many other improvements that may be required by the Settlement Agreement or by the Central and South Florida Flood Control Project. For example, it is possible that scheduled releases from Lake Okeechobee will require treatment prior to discharge to the ENP to maintain phosphorus levels at the levels required by the SWIM Plan. The Plan also does not address the cost of storage areas within or downstream of the EAA to detain EAA runoff when the existing canals cannot handle the diverted flows.

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ALGAL TURF SCRUBBERS

Algae have long been recognized for efficient nutrient uptake at low concentrations and for extremely high productivity levels when sufficient nutrients are available. Algal turf scrubber (ATS) systems are engineered to make use of complex algal communities to manage water quality or to scrub nutrients or contaminants from a water source.[21] For the Everglades Protection Project, algal turf scrubbers have been proposed as a treatment method for removing phosphorus in drainage waters from the EAA. The Smithsonian Institute holds a patent on the algal turf scrubbing process. BioEnvironmentals, Inc. holds an exclusive North American license for agricultural use of the process.

Overview of Technology

While algae treatment systems have been used in a variety of marine, estuarine, and freshwater applications, engineered scrubbing systems have been used primarily for research and demonstration projects and for maintaining water quality in aquariums. These systems have been small in scale and have not included the harvesting and disposal of biomass that are required for much larger scale systems.

For application in the EAA, an experimental algal turf scrubbing system was designed by BioEnvironmentals, Inc. A prototype was constructed in the sugar cane region of the EAA about 25 miles south of Lake Okeechobee. The prototype has been in operation as a pilot facility since November 1991 using water from a secondary drainage canal as influent.

As currently proposed, EAA drainage water would be introduced into long, narrow channels called "flow-ways" which would be lined with a textured geosynthetic membrane. Algae, attached to the membrane, would treat the water as it passes through the flow-ways. Each flow-way would be approximately 22 feet wide and approximately 750 feet long and would accommodate a flow of about 220 gallons per minute (10 gpm per foot of width). Water depth in the flow-ways would be on the order of 8 to 12 inches. Wave action would be induced to promote diversity of algal species and algal productivity.

Approximately every 7 days in summer and 9 to 10 days in winter, the algae in the flow-ways would be harvested to keep a stable phosphorus removal efficiency. A specially designed mobile harvester would be used for the harvesting. The harvester would ride along the top of the flow-way and use suction to remove the algae from the flow-way. The biomass would be partially dewatered in a separator unit and then pumped to a spoils area for processing prior to transport off-site for marketing or disposal. Detailed discussions of the proposed flow-way and harvester designs have been presented.[21,22] However, no harvester has been manufactured and field tested and no detailed proposals have been developed for the processing and disposal of the biomass for a large-scale application.

Operational data from the 50-foot-long pilot test facility suggest that phosphorus reduction is a function of influent phosphorus concentration. In a single 50-foot pass, removals were found to vary linearly at the rate of about 17 ppb per 100 ppb of influent total phosphorus.[23] For influent concentrations of about 130 ppb, reductions of about 20 ppb were observed; whereas for influent concentrations of about 50 ppb, reductions of about 7 ppb were observed. Scale-up from the 50-foot-long pilot facility assumes that additional removal can be achieved at the same rates by increasing the length of the flow-ways in proportion to overall phosphorus reduction requirements.

Basis of Evaluation

Given the modular construction features of the proposed algal turf scrubbers, it is possible to consider them at all scales of application and influent phosphorus loadings. Although questions concerning the ability to scale up exist, pilot test data presented by BioEnvironmentals, Inc. suggest that 750-foot-long algal turf scrubbers should be capable of reducing TP concentrations in EAA drainage water from 0.15 mg/l to about 0.02 mg/l or less. Assuming that an effluent TP concentration of 0.02 mg/l could be maintained on a consistent basis, a basin scale treatment facility using algal turf scrubbers would need to have a 900-mgd capacity to achieve 75 percent TP removal. Rather than reducing plant capacity to achieve 50 and 25 percent TP removals, it was assumed that scrubber length would be reduced to 500 feet and 250 feet, respectively. Scrubber width was assumed to remain constant at 22 feet for all scales of application and phosphorus removal levels. Because of the highly variable flow rates that must be accommodated, and because the scrubbers must be kept wet at all times, it was assumed that a flow recirculation system would be provided.

Presented in Table 3-8 are estimates of scrubber treatment area, biomass production, total land area, and capital cost associated with algal turf scrubber treatment facilities at the four scales of application in the EAA. At a typical basin scale treatment facility, about 2,840 scrubbers would be required to provide the 900-mgd capacity. At the subbasin and farm scales, the number of scrubbers required would be 284 and 47, respectively.

A 750-foot scrubber takes up to about 0.4 acres of land. The shorter scrubbers take up proportionally less land area. In estimating total land area requirements, an additional 25 percent of scrubber surface area was assumed to be required for buffer, residuals management, and operation and maintenance facilities.

In estimating the capital cost of algal turf scrubber treatment facilities in this evaluation, it was assumed that water would be pumped into the flow-ways from the canals. BioEnvironmentals, Inc. estimates the cost of the actual flow-way treatment cells to be approximately \$1.68 per square foot of surface area. This estimate has been reviewed by the Jacobs Engineering Group, Inc.[25] and was assumed to be reasonable for scrubber construction. Harvesters were assumed to cost \$75,000 each. It was assumed that one harvester would be provided for every 50 scrubbers. To estimate solids handling requirements, an average productivity of 20 grams of dry solids per day per square meter (g/day/m^2) of scrubber area was assumed based on flow-way pilot plant data presented by BioEnvironmentals, Inc.[21] At a design flow rate of 900 mgd, the solids generation rate would be almost 100 dry tons per day for a basin scale facility treating to the 75 percent phosphorus removal level. Proportionally less biomass would be produced at the smaller scales of application and lower phosphorus removal levels. Because of the large quantities of biomass to be produced, it was assumed that mechanical dewatering would be provided (without conditioning) using equipment such

Table 3-8 Basis of Evaluation for Algal Turf Scrubbers

Parameter	Scale of application							
	Basin		Subbasin		Farm		Point source	
	Scale unit	Total EAA	Scale unit	Total EAA	Scale unit	Total EAA	Scale unit	Total EAA
Design flow, mgd								
25 percent P removal	900	3,600	90	3,600	15	2,550	15	105
50 percent P removal	900	3,600	90	3,600	15	2,550	15	105
75 percent P removal	900	3,600	90	3,600	15	2,550	15	105
Required scrubber area, acres								
25 percent P removal	359	1,436	36	1,440	6	1,038	6	42
50 percent P removal	717	2,868	72	2,880	12	2,076	12	84
75 percent P removal	1,076	4,304	108	4,320	18	3,114	18	126
Biomass production at design flow, dry tons per day								
25 percent P removal	32	128	3	128	0.5	86	0.5	3
50 percent P removal	63	252	6	252	1.0	173	1.0	7
75 percent P removal	95	380	9	380	1.6	277	1.6	11
Land area required, acres								
25 percent P removal	448	1,792	45	1,800	8	1,384	8	56
50 percent P removal	897	3,588	90	3,600	15	2,595	15	105
75 percent P removal	1,345	5,380	135	5,400	22	3,806	22	154
Capital cost,[a] million dollars								
25 percent P removal	59	236	7	295	3	457	3	19
50 percent P removal	108	433	12	498	3	594	4	25
75 percent P removal	158	634	18	700	4	731	4	30

[a] 1992 dollars.

as filter presses or screw presses. Biomass dewatering equipment was sized to accommodate the maximum generation rates indicated in Table 3-8. Dewatering equipment generally accounted for about 10 percent of the total cost of the ATS treatment facilities.

Evaluation Results

Presented in Exhibit 3-8 are the ratings given to algal turf scrubbers at the various scales of application and phosphorus removal levels. The technology received its highest ratings at the individual farm scale and its lowest ratings at the basin scale.

Algal turf scrubbers have significant phosphorus reduction capability, particularly at the smaller scales of application and lower percentages of removal. Implementation by 1997 will be difficult at the smaller scales of application and will be very unlikely at the basin and subbasin scales. Without flow equalization, there should be little, if any, change in hydroperiod and there should be only minimal operational impacts on the Central and South Florida Flood Control Project. At the farm scale, it is possible that only construction permits and stormwater management permits will be required. However, NPDES permits are likely to be required at the other scales of application.

Algal turf scrubbers have been pilot tested in the field only and, therefore, receive relatively low ratings for previous application of technology. Capital costs appear to be substantially greater than the constructed wetland base case alternative when all cost factors are included. Operation and maintenance requirements are anticipated to be much higher than currently projected by BioEnvironmentals, Inc., particularly when residuals management is included in the analysis. Land area requirements for algal turf scrubbers are significantly less than for the base case wetland system, particularly when flow equalization storage is not considered in the analysis.

Discussion of Evaluation Results

Algal turf scrubbers have the potential to remove phosphorus from EAA drainage waters at very low influent concentrations as evidenced by the performance data compiled from the pilot plant constructed in the EAA. However, it is not clear that performance in full-scale, 750-foot-long scrubbers can be estimated from linear extrapolation of data from the 50-foot-long pilot plant. For example, it is questionable that the wave action that has been shown to be so important to process performance and species diversity in the pilot plant can be maintained in the 750-foot-long scrubbers at the shallow water depths proposed. The requirement for multiple full-scale scrubbers increases the uncertainty that high percentages of low level influent phosphorus can be removed consistently.

The fact that performance of algal turf scrubbers has not been demonstrated at full scale is a serious disadvantage in this evaluation. Many of the engineering details are still in the conceptual stage and must be subjected to field testing for the first time. Of particular concern are the methods to be used for harvesting, transport, storage, and processing of the biomass produced from the scrubbers. At the basin and subbasin scales, the large quantities of this material will create odor problems, and operating requirements associated with residuals management will probably be significant. There are several potential markets (albeit undeveloped at this time) for algal products from

Exhibit 3-8 Phase I Evaluation Ratings for Algal Turf Scrubbers

Criterion	Criterion weighting[a]	Scale of application/level of phosphorus reduction[b]											
		Drainage basin			Subbasin			Individual farm			Point source		
		25	50	75	25	50	75	25	50	75	25	50	75
Phosphorus removal capability	3	6/18	4/12	2/6	6/18	4/12	2/6	6/18	4/12	2/6	6/18	4/12	2/6
Implementation schedule	2	2/4	2/4	2/4	2/4	2/4	2/4	4/8	4/8	4/8	4/8	4/8	4/8
Hydroperiod impact	2	5/10	5/10	5/10	5/10	5/10	5/10	5/10	5/10	5/10	5/10	5/10	5/10
Impact on C&SF Project	2	7/14	7/14	7/14	7/14	7/14	7/14	7/14	7/14	7/14	7/14	7/14	7/14
Permitting requirements	2	4/8	4/8	4/8	4/8	4/8	4/8	7/14	7/14	7/14	4/8	4/8	4/8
Previous application of technology	2	3/6	3/6	3/6	3/6	3/6	3/6	3/6	3/6	3/6	3/6	3/6	3/6
Capital cost	1	5/5	4/4	3/3	4/4	4/4	3/3	4/4	4/4	3/3	6/6	7/7	6/6
O&M requirements	1	4/4	4/4	4/4	4/4	4/4	4/4	3/3	3/3	3/3	5/5	5/5	5/5
Economic impacts	1	8/8	8/8	8/8	8/8	8/8	8/8	8/8	8/8	8/8	10/10	10/10	10/10
Total		77	70	63	76	70	63	85	79	72	85	80	73

[a] Criteria directly related to satisfying provisions of SWIM Plan receive a weighting of 2 or 3; all other criteria receive a weighting of 1.
[b] Phosphorus reduction levels of 25, 50 and 75 percent of the influent phosphorus estimated for each scale of application.

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the ATS system. Uses for algae in the pharmaceutical industry, and as human food supplements, animal feed, and fertilizer have been reported in recent years. Recent research by the University of Florida indicates that the algae produced at the Everglades pilot plant showed potential as a soil amendment. Marketability will depend to a large extent on the species of algae produced in the treatment system. Diversified algae species have been observed at the pilot plant, which is desirable from a treatment perspective. This diversified algal crop, however, may not be good from a marketing perspective. If markets for the biomass material are not found, disposal or additional processing could also be a problem. To date, the residuals management aspects of this technology have not been defined to the same degree as the engineering aspects of the scrubber units themselves.

In summary, algal turf scrubbers represent a promising technology with significant potential for removing phosphorus from drainage waters in the EAA. The technology appears to be best suited for application at the individual farm or point source scales. Full-scale field testing could demonstrate similar viability at larger scales of application, but it is doubtful that the necessary facilities could be constructed by 1997 at those scales. The potential impact of harvesting and residuals management on the successful application of this technology at any scale is significant. Any future full-scale field testing should include procedures for harvesting, processing, marketing, and/or disposing of the residual biomass.

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NUTRIENT MANAGEMENT SYSTEM

The nutrient management system (NMS) is a managed biological treatment system developed several years ago by Bion Technologies, Inc. It has been applied primarily at dairy farms for treatment of barn wastes and surface runoff, including two farms north of Lake Okeechobee. Recently, Bion has proposed that the NMS be used for treatment of agricultural runoff from the EAA. A pilot plant currently is being planned for construction in the EAA to test the phosphorus removal performance of the process on agricultural drainage water.

Overview of Technology

As applied for dairy wastes, the NMS is a sequence of physical, chemical, and biological treatment processes. Treatment units include (1) a solids separator; (2) a bioreactor, with optional chemical feed; (3) an ecoreactor; and (4) an optional georeactor, if necessary, for additional phosphorus removal. Depending on flow rates, waste characteristics, and effluent requirements, multiple units or treatment cells can be provided.

The solids separator unit is a shallow excavated area or basin where readily settleable material is removed from the waste stream. The bioreactor is a large pond that receives the settled wastewater. Anaerobic treatment is provided at the front end of the pond with aerobic treatment being provided at the back end using surface aeration. Chemical addition can be provided at the bioreactor to assist in the removal of phosphorus or other constituents, as necessary.

The ecoreactor is a marsh or wetland type treatment unit, constructed of containment berms and subdivided into cells by smaller, internal berms. The ecoreactor supports diverse populations of plants, animals, and microorganisms. The ecoreactor is kept wet at all times to promote biological uptake of nutrients and other constituents. Periodically during the summer, ecoreactor cells are dewatered and vegetative growth is harvested from the system. Bottom sediments also can be dredged out every several years to remove additional nutrients. The managed approach to the natural treatment process is intended to allow increased constituent loadings and reduced land area requirements in contrast to a traditional unmanaged wetlands treatment system. In the publication entitled Bioremediation Report, Bion reports typical phosphorus loading rates to the ecoreactors of between 0.5 and 2 pounds of phosphorus per acre per day (lb/acre/day) based on dairy waste treatment applications.[26]

The georeactor is an engineered soil matrix constructed beneath the ecoreactor which is intended to adsorb and filter out additional constituents such as phosphorus. The georeactor is composed of gravel and clay (if these materials are available) to promote hydraulic transmissivity as well as to provide adsorption capacity. Evacuation wells pull some of the water from the ecoreactor through the georeactor and discharge it back to the bioreactor and/or ecoreactor to provide an internal flow recycle system for process control.

Surface water passing through the ecoreactor flows into a water holding area, or polishing pond. This pond contains a diverse population of aquatic plant, animal, and microbial species. No harvesting is accomplished in the water holding area.

Bion reports phosphorus and nitrogen removal levels in excess of 95 percent at its dairy waste treatment operations. Influent TP concentrations as high as 40 mg/l have been reduced to about 1 mg/l using the NMS technology. However, the difference in constituent concentrations (e.g., solids, phosphorus, nitrogen, and degradable carbon) between dairy wastes and drainage water from the EAA is significant. Dairies typically produce a low-volume (less than 1 mgd), high-strength waste-water, whereas drainage water from the EAA is generated in very large volumes, is subject to extreme variations in flow rate, and has much lower concentrations of solids, phosphorus, and degradable carbon.

It is unclear how Bion intends to apply the NMS technology to treatment of drainage water from the EAA. Bion has been reluctant to discuss their plans due to the proprietary nature of the technology. Certainly, modifications to the treatment scheme used at the dairies will be necessary. Bion is planning to construct a pilot plant in the EAA to test the capability of the NMS technology to remove phosphorus at the very low concentrations found in EAA drainage water. The pilot facility will receive drainage from a 12-acre fallow field surrounded by sugar cane. The specific treatment process train and the flow and constituent loadings to be used for treatment units at the pilot plant are not available. However, it is probable that the low influent constituent concentrations will have a dramatic impact on the size and configuration of treatment units in the NMS system.

Basis of Evaluation

Preliminary discussions with Bion indicate that only ecoreactors and georeactors would be used for treatment of EAA drainage water due to its low solids and phosphorus concentrations. If this is the case, the treatment system becomes similar to a constructed wetland system, which would be managed to include periodic harvesting of vegetative growth and partial flow recycle through soil for adsorption of phosphorus.

Bion estimates that using a phosphorus loading rate of 2.3 lb/acre/day, the NMS technology should be able to remove 50 to 80 percent of the phosphorus in drainage water from the EAA.[29] This would seem to be very optimistic. This loading rate, which is similar to that used for treatment of dairy waste, is far in excess of the loading rate used in sizing the STAs, which is on the order of 0.01 lb/acre/day of phosphorus (0.5 gm/m^2/day). The higher loading rates are applicable for dairy wastes containing high concentrations of phosphorus. Even if credit is given for removal of phosphorus by harvesting of biomass and for partial recycling of flow, a phosphorus loading rate of 2.3 lb/acre/day is not reasonable for the required level of performance from a wetlands type treatment system.

For the purposes of this evaluation, a phosphorus loading rate of 0.20 lb/acre/day for the ecoreactors was assumed for a target removal rate of 75 percent. Phosphorus loading rates of 0.25 and 0.30 lb/acre/day were assumed for removal levels of 50 and 25 percent, respectively. While this loading rate is an order of magnitude lower than what Bion proposes, it is an order of magnitude higher than what would normally be used for natural wetland treatment systems.

Sizing of the ecoreactors was based on the flows, phosphorus concentrations, and methodology described in Chapter 2. As a diversified and managed wetlands system, the NMS technology, if properly designed and operated, has the potential to achieve effluent TP concentrations lower than those that would be expected from natural wetland systems. For the purposes of this evaluation, an effluent concentration of 0.03 mg/l was assumed. From Figure 2-1, a design flow capacity of 1,200 mgd would be required to provide 75 percent TP removal at the basin scale if this effluent TP concentration could be achieved consistently. Design flows, dike lengths, land area requirements, and capital cost estimates for implementation of the NMS technology at the various phosphorus removal levels and scales of application in the EAA are presented in Table 3-9. It was assumed for costing purposes that dikes would be constructed above grade and that drainage water would be pumped from canals into the treatment system. It was further assumed that the ecoreactor/georeactor cells would be constructed as 100-acre squares and configured in a grid pattern to reduce cost. Dike construction was estimated to cost $600,000 per mile and ecoreactor/georeactor construction was estimated to cost $3,000 per acre. Land area requirements for ecoreactor/georeactor cells were estimated based on phosphorus loading. An additional 25 percent at the basin and subbasin scales, and an additional 50 percent at the farm and point source scales, was included to allow for dike construction, buffer zones, residual solids management, and equipment storage.

It was assumed that residual solids would not require mechanical dewatering and disposal, but rather would be dried on-site and used locally as a feed supplement or fertilizer. The capital cost of solids handling facilities was estimated at 5 percent of the treatment unit construction cost.

<u>Evaluation Results</u>

The evaluation ratings given to the NMS technology are presented in Exhibit 3-9. The technology received its highest overall rating at the point source scale and lower overall ratings at the other scales of application. This would seem reasonable since process wastewater from point source discharges is a lower volume, higher strength waste stream and more closely approximates the type of application for which the NMS technology has been used to date.

The NMS technology received relatively low scores for phosphorus removal capability, permitting requirements, and previous applications of technology because its performance on drainage waters with very low phosphorus concentration has not been demonstrated in the laboratory or in the field. Land area requirements and capital costs would be expected to be less than for the base case wetlands alternative, but operating requirements could be substantial, particularly at the higher phosphorus removal levels. Some improvement to hydroperiod in the Everglades could also be expected due to dampening of peak flows. Operational impacts on the Central and South Florida Flood Control Project would probably be minor.

Table 3-9 Basis of Evaluation for Nutrient Management System

Parameter	Scale of application							
	Basin		Subbasin		Farm		Point source	
	Scale unit	Total EAA	Scale unit	Total EAA	Scale unit	Total EAA	Scale unit	Total EAA
Design flow, mgd								
25 percent P removal	1,200	4,800	120	4,800	20	3,400	15	105
50 percent P removal	1,200	4,800	120	4,800	20	3,400	15	105
75 percent P removal	1,200	4,800	120	4,800	20	3,400	15	105
Dike length, miles								
25 percent P removal	41	164	7	280	2	346	8	56
50 percent P removal	47	188	7	280	2	346	10	70
75 percent P removal	60	240	9	360	2	346	11	77
Land area required, acres								
25 percent P removal	4,691	18,765	563	22,518	92	15,966	521	3,649
50 percent P removal	5,630	22,518	676	27,022	111	19,159	626	4,379
75 percent P removal	7,037	28,148	844	33,777	138	23,948	782	5,473
Capital cost,[a] million dollars								
25 percent P removal	83	330	13	510	4	660	13	92
50 percent P removal	95	382	14	565	4	706	16	109
75 percent P removal	116	466	17	688	5	853	18	124

[a] 1992 dollars.

Exhibit 3-9 Phase I Evaluation Ratings for Nutrient Management System

Criterion	Criterion weighting[a]	Scale of application/level of phosphorus reduction[b]											
		Drainage basin			Subbasin			Individual farm			Point source		
		25	50	75	25	50	75	25	50	75	25	50	75
Phosphorus removal capability	3	8/24	6/18	4/12	8/24	6/18	4/12	8/24	6/18	4/12	9/27	7/21	5/15
Implementation schedule	2	5/10	4/8	3/6	5/10	4/8	3/6	4/8	3/6	2/4	8/16	8/16	8/16
Hydroperiod impact	2	7/14	7/14	7/14	7/14	7/14	7/14	6/12	6/12	6/12	6/12	6/12	6/12
Impact on C&SF Project	2	8/16	8/16	8/16	8/16	8/16	8/16	8/16	8/16	8/16	8/16	8/16	8/16
Permitting requirements	2	4/8	4/8	4/8	4/8	4/8	4/8	3/6	3/6	3/6	4/8	4/8	4/8
Previous application of technology	2	3/6	3/6	3/6	3/6	3/6	3/6	3/6	3/6	3/6	3/6	3/6	3/6
Capital cost	1	4/4	5/5	4/4	3/3	4/4	3/3	3/3	4/4	3/3	2/2	2/2	2/2
O&M requirements	1	4/4	4/4	4/4	4/4	4/4	4/4	3/3	3/3	3/3	4/4	4/4	4/4
Economic impacts	1	8/8	8/8	7/7	7/7	7/7	6/6	8/8	8/8	8/8	8/8	8/8	8/8
Total		94	87	77	92	85	75	86	79	70	99	93	87

[a] Criteria directly related to satisfying provisions of SWIM Plan receive a weighting of 2 or 3; all other criteria receive a weighting of 1.
[b] Phosphorus reduction levels of 25, 50 and 75 percent of the influent phosphorus estimated for each scale of application.

7016EX3-9

Discussion of Evaluation Results

In theory, the NMS technology has potential to be effective in removing phosphorus and, as a highly managed natural treatment system, offers several advantages over unmanaged systems. The most important of these for the EAA is the potential for reduced land area requirements compared with the wetlands treatment system currently being proposed. However, the technology is still unproven in treating low strength drainage waters in very high volumes. Phosphorus loading rates to the ecoreactor may need to be considerably lower than that assumed in this evaluation. Furthermore, the sand and muck soils available in the EAA have highly variable adsorptive capacity and may prove to be of marginal value for use in the georeactor depending on location. Numerous questions concerning the performance reliability of the NMS technology must be answered before it can be seriously considered for large-scale application in the EAA. Data from the planned pilot plant project may offer answers to these questions.

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OZONE TREATMENT

Ozone is a strong oxidizing agent and disinfectant. It has been used to oxidize organic and inorganic compounds and to kill bacteria and viruses in water and wastewater. It has also been used to enhance flocculation and clarification in some cases for drinking water treatment. Ozone treatment has been suggested by Mar-Clar, Inc. as an alternative treatment technology for reducing phosphorus discharges from the EAA. Mar-Clar markets the Ecozone System which is a proprietary ozonation system.

Overview of Technology

The Ecozone System is a new technology which has been available commercially for about 2 years. It involves treatment with ozone, ultraviolet light, activated carbon (if necessary), and proprietary blends of insoluble, inorganic catalytic agents to enhance the speed and effectiveness of the chemical reactions that take place. Because of ozone's strong oxidizing potential, the Ecozone System has been proposed for a variety of applications including treatment of water supplies, domestic, industrial, and agricultural wastewaters, and landfill leachate. However, due to its proprietary nature, no specific information is available on the treatment processes or the sequence in which they are applied.

The use of ozone for phosphorus removal is questionable. Phosphorus must either be removed as a precipitate in a sedimentation or filtration process or be adsorbed onto the surface of an adsorbent as in an ion exchange process. While it is possible that ozone can enhance both processes, ozone by itself has little value for phosphorus removal.

The developers of the Ecozone System are unsure of the phosphorus removal mechanisms that take place in their reactors. Their theory is that phosphorus is removed as calcium phosphate with the catalytic agents acting to enhance the process. Test results on final effluent from a sewage treatment plant in Sarasota, Florida indicate 93.3 percent removal of phosphorus, from 5.28 mg/l to 0.35 mg/l. However, no information is available on the specific treatment processes, detention times, chemical dosages, or removal mechanisms involved.

The Ecozone System is sold in modular treatment units, the largest of which has a capacity of 100,000 gallons per day (gpd). If larger flows require treatment, multiple units are provided. It is also possible to recycle flows through the Ecozone System to achieve the necessary effluent quality. While numerous demonstrations of the technology have been performed on a variety of different wastewaters, the technology has never been tested on agricultural drainage water such as that requiring treatment in the EAA. There are no full-scale units currently in operation.

Basis of Evaluation

For this evaluation, it was assumed that the appropriate number of 100,000 gpd Ecozone System modules could be provided to treat flows at all four scales of application in the EAA. If it is assumed, theoretically, that the same 93 percent TP removal efficiency obtained on wastewater treatment plant effluent in Sarasota could be achieved on EAA drainage water, the average effluent

TP concentration would be about 0.01 mg/l, or 10 ppb. At this effluent TP concentration, flow capacity for a basin scale treatment facility would need to be about 700 mgd to achieve 75 percent TP removal on an average annual basis. Treatment capacities of 380 and 180 mgd at the basin scale would be required to achieve 50 and 25 percent removals, respectively. Proportionally lower treatment capacities would be required at the smaller scales of application.

The number of treatment modules required, the land area requirements, and the estimated capital costs for implementation of ozone treatment at each scale of application in the EAA are presented in Table 3-10. In computing the number of treatment modules required at the basin, subbasin, and farm scales, it was assumed that single pass treatment could achieve the required effluent TP concentration and that 20 percent additional units would be maintained for standby purposes. At the point source scale, it was assumed that two passes through the treatment equipment would be required because of the higher influent TP concentration.

The land area required for siting of the Ecozone System equipment is reportedly very low.[30] In this evaluation, each module was assumed to require an average of 500 square feet of floor space. Operating requirements are also reported to be very low. Electrical costs are estimated to be about $2 per hour.[30] No estimates are available for labor requirements, however.

The estimated cost per module is $280,000.[30] To this must be added the cost of land, buildings, site preparation, pumping stations, utilities, and all other improvements necessary for a complete treatment facility. It was estimated that these additional improvements would increase this cost by at least 25 percent, making the total cost per module about $350,000.

Evaluation Results

The results of the evaluation of the Ecozone System treatment technology are summarized on Exhibit 3-10. Because it is a new and undefined technology and because its performance related to phosphorus removal at the low levels required for protection of the Everglades has not been demonstrated, it received low ratings for all performance-based criteria. Potential benefits of a modular treatment technology such as the Ecozone System include reduced land area and operating requirements. However, capital costs for the system, as currently marketed, are prohibitive except perhaps for very small scale applications.

Discussion of Evaluation Results

Detailed demonstration testing of the Ecozone System treatment technology on drainage water and point source discharges from the EAA is necessary before it can be given serious consideration. Mar-Clar has offered to perform this testing at no cost. If sufficient phosphorus removal data and other information regarding the treatment mechanisms involved can be provided, then further consideration of the technology may be warranted. However, it is doubtful that a technology based primarily on ozone oxidation can be shown to compare favorably with other technologies when the specific treatment objective is the removal of phosphorus to very low levels, as is required in the EAA.

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[redacted]

SEDIMENT DREDGING

Sediment dredging has been proposed as an alternative technology to reduce phosphorus loads discharged from the EAA through the removal of sediments that have been deposited on canal bottoms. While the presence of sediments in the District's canals has been documented, there is some question regarding their source and their impact on the phosphorus load leaving the EAA.

Overview of Technology

The Florida Sugar Cane League (FSCL) and its consultants have estimated that approximately 50 percent of the total phosphorus leaving the EAA is in the particulate form, based on their review of District water quality data.[32] The FSCL also has commissioned studies by Hutcheon Engineers that document a substantial buildup of sediments in farm canals as well as the District's canals. Sediments being pumped out of farm canals contribute directly to the buildup of sediments in District canals. The District's weed control program could also be a contributing source of sediments in the canals. Sediment depths of up to 3 feet or more were observed at 15 sampling locations in the District's primary canal system.[32] The FSCL believes that this buildup of sediments contributes to the total phosphorus load leaving the EAA through the District's primary pumping stations.

No data are available currently to determine what percentage of the current phosphorus load discharged from the EAA results directly from the presence of sediments on the canal bottoms. It is expected that sediments contribute to the particulate phosphorus load as the result of scour near the pumping stations and that some phosphorus is also resolubilized and released into the water column in the dissolved form as well. It is believed that if these existing sediments could be removed from the canals, there would be an immediate reduction in the phosphorus load leaving the EAA. The District is currently planning to undertake a series of experiments to evaluate the contribution of sediments in its canals to the existing phosphorus load.

Sediments from most secondary farm canals are most economically removed with a dragline or bucket-loading piece of equipment due to their narrow width and shallow depth. The FSCL has proposed to use hydraulic dredges for the removal of sediments from the bottoms of primary farm canals. Hydraulic dredging also would be applicable for the removal of sediments from the District's canals.

The hydraulic dredges proposed for use in the EAA are relatively small and maneuverable and have a draft in the water of only about 1 foot. Each dredge is equipped with a 2,400-gpm pump and is capable of pumping dredged material up to 1,000 feet without significant reduction in performance. The solids content of the dredged material depends on its physical properties and varies as the dredge moves from the newer surficial sediments down to material near the canal bottom. The Florida Sugar Cane League is planning to test a dredge on primary farm canals in the next several weeks to better estimate how it will perform in removing sediments from canals in the EAA.

Two important aspects of the sediment dredging operation are (1) handling and disposal of the sediments that are removed from the canals, and (2) management of the large volume of water that is pumped out with the sediments. For farm canals, the FSCL proposes that dredged material be stockpiled and dried on the banks of the canals, similar to typical maintenance dredging operations.[33] The water with the sediments would be allowed to drain off onto the fields or into secondary canals for irrigation purposes. When the sediment is dry enough to be worked, it would be spread onto the fields using a bulldozer or other farm equipment.

If the water pumped from canals is to be used on active fields for irrigation, irrigation requirements could become a limiting factor in how fast the dredging operation can be accomplished. First, the dredging operation would be more appropriate during the dry season of the year when irrigation is required. Second, the water pumped from the canals could not exceed the maximum irrigation rate for the crops involved. If dredging is accomplished when irrigation is not required, or if the dredge pumps more water than is required for irrigation purposes, a system for returning water to the canals, free of sediments, would need to be developed and utilized.

For sugar cane, the irrigation rate is typically about 0.25 inches of water per day. On an 80-acre block, this would amount to about 540,000 gallons of irrigation water per day. Assuming a square block configuration, 1,867 feet on a side, and fields on both sides of the canals, the dredge would have to travel at a maximum rate of about 4 feet per minute to avoid over-irrigation of the fields if it pumps at a rate of 2,400 gpm. In practice, it may not be necessary for the dredge to move this fast, depending on actual pumping rate and how the water actually is distributed onto the fields. The test program to be conducted by the FSCL should yield important data on the performance of the dredge and information on how best to manage the sediments and water that are pumped from the canals.

Disposal of sediments and water pumped from farm canals may be possible on active fields since the dredging can be accomplished in increments during different seasons of the year. Dredging of District canals, however, probably requires the use of designated spoil areas to allow dredging to continue during all seasons of the year. These spoil areas would be located immediately adjacent to the District canal system.

Basis of Evaluation

For this evaluation, it was assumed that sediment dredging will be accomplished in the District's canals as a one-time activity designed to reduce the existing phosphorus load discharged through the District's four primary pumping stations. Sediment dredging in farm canals was not included in this evaluation. Although sediment dredging has been proposed for farm canals as well as District canals, the technology is just one of several options available to farm owners for keeping sediments from being discharged into the District's canals. It therefore can be looked at in much the same way as an on-farm BMP. If the District's canals can be dredged thoroughly one time, and farmers are conscientious about keeping sediments from leaving their canals by whatever BMP is most appropriate (sediment traps, dredging, etc.), then the benefit of dredging the District's canals can be realized for many years into the future. Sediment dredging at the farm scale will be considered with other BMPs as part of the evaluation of on-farm phosphorus reduction measures.

Dredging of the District's canals was evaluated only at the basin scale of application and only at the 25 percent phosphorus removal level. In the evaluation of other treatment technologies, it was conservatively assumed that particulate phosphorus accounts for only 25 percent of the total phosphorus load discharged through the District's pumping stations. For this technology, the more liberal assumption was made that particulate phosphorus makes up as much as 50 percent of the total phosphorus load. While no data are available to suggest how much of the total phosphorus load results directly from the presence of sediments in the District's canals, it has been assumed for this evaluation that 25 percent of the total load is contributed by the canal sediments. It is very doubtful that the direct contribution of bottom sediments to the total phosphorus load is 50 or 75 percent. Therefore, sediment dredging as a treatment technology was not evaluated at these higher phosphorus removal percentages.

Performance data for hydraulic dredges operating on the District's canals are not available. It was assumed, based on discussions with a dredging firm in Louisiana, that the dredges proposed by the FSCL can remove an average of about 800 cubic yards of sediment per 8-hour day. An average solids content of about 10 percent was assumed. The dredges lease for about $200 per hour, including fuel and operators. There are about 120 miles of District canals. Assuming an average of 3 feet of sediment and an average canal width of 50 feet, approximately 3.5 million cubic yards of sediment material would be dredged out of the District canals.

In this evaluation, it was assumed that dredging would occur year-round and that land on both sides of the District canals would be taken out of cultivation and leased to provide for disposal of the sediments and water pumped from the canals. With this approach, all District canals can be dredged in 1 year if about 15 dredges are used.

To determine land area requirements, it was assumed that an average of 100 feet on both sides of the canals would be needed for sediment storage and drying. This amounts to about 3,000 acres of land. Another 11,000 acres of land would be needed for disposal of water, assuming that fields could be flooded to a depth of 24 inches. Since phosphorus concentrations in the water pumped out of the canals with the sediments could be high, it was assumed that this water could not be returned directly to the canals. Rather, it was assumed that the water would be discharged onto adjacent fields and allowed to percolate through the soil before reentering the canal. It was assumed that the cost of leasing land for the dredging operations would be about $600 per acre based on the typical annual revenue generated from an acre of sugarcane.

Total land area requirements and the total estimated cost of dredging the approximately 120 miles of District canals are presented in Table 3-11. It is estimated that the total capital cost of the one-time dredging operation would be about $34 million.

Table 3-11 Basis of Evaluation for Sediment Dredging

Parameter	Value
Canal length dredged, miles	120
Sediment removed	
Average depth in canal, feet	3
Total volume, million cubic yards	3.5
Average solids concentration, percent	10
Land area required, acres	14,000
Capital cost, million dollars	34

Evaluation Results

The evaluation ratings given to sediment dredging at the basin scale of application and 25 percent phosphorus removal level are presented in Exhibit 3-11. The technology received a less than average rating for phosphorus removal capability because it has not been documented how much bottom sediments actually contribute to the phosphorus load discharged from the EAA. Implementation of the technology would not have any positive impact on hydroperiod in the Everglades. However, the technology receives high ratings against all other criteria. Probably the most important advantages of sediment dredging are that (1) it can be implemented quickly, (2) it involves use of agricultural land for a period of 1 year or less, and (3) it costs significantly less than other treatment technologies. The most important disadvantage is the uncertainty over how much reduction in phosphorus discharge can actually be achieved by dredging operations.

Discussion of Evaluation Results

Sediment dredging has the potential to be one of the most cost-effective treatment technologies available to the District for reducing phosphorus discharges from the EAA. For this potential to be realized, two important conditions must be documented. First, it must be shown that bottom sediments in the District canals are contributing directly to the phosphorus load leaving the EAA, either by phosphorus resolubilizing into the water column or by solids being scoured off the bottom. Second, it must be demonstrated that the hydraulic dredges can remove a high percentage of the sediments from the bottom of the District's canals and that the dredged material and water can be managed effectively on land along the canal banks.

Demonstration testing by the Florida Sugar Cane League should answer most questions concerning the performance of the dredges and the cost of the dredging operation. However, before sediment dredging can be considered seriously, it is necessary that studies be undertaken to determine the impact of its implementation on the phosphorus load being discharged from the EAA.

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Exhibit 3-11 Phase 1 Evaluation Ratings for Sediment Dredging

Criterion	Criterion weighting[a]	Scale of application/level of phosphorus reduction[b]											
		Drainage basin			Subbasin			Individual farm			Point source		
		25	50	75	25	50	75	25	50	75	25	50	75
Phosphorus removal capability	3	4/12											
Implementation schedule	2	8/16											
Hydroperiod impact	2	6/12											
Impact on C&SF Project	2	8/16											
Permitting requirements	2	8/16											
Previous application of technology	2	9/18											
Capital cost	1	10/10											
O&M requirements	1	10/10											
Economic impacts	1	8/8											
Total		118											

[a] Criteria directly related to satisfying provisions of SWIM Plan receive a weighting of 2 or 3; all other criteria receive a weighting of 1.
[b] Phosphorus reduction levels of 25, 50 and 75 percent of the influent phosphorus estimated for each scale of application.

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WETLANDS

Constructed wetland treatment systems in the form of four large Stormwater Treatment Areas (STAs) are currently proposed for implementation as part of the District's SWIM Plan. The District also has evaluated wetland treatment at the farm scale in the form of Farm Treatment Areas (FTAs). The technology does not involve intensive management of the treatment processes that occur in the wetlands. Rather, the treatment areas are allowed to evolve and perform in a fashion similar to the Water Conservation Areas (WCAs). In this section, the STAs and FTAs are evaluated to allow comparison with the other treatment technologies being considered in this investigation.

Overview of Technology

Wetlands have been utilized for the treatment of domestic wastewater in the United States and Canada throughout the twentieth century. During the last decade, worldwide interest in the use of wetlands to treat wastewater has grown considerably. The greatest emphasis has been on the treatment of domestic wastewater; however, significant work has also been accomplished on the use of wetlands for treatment of agricultural and dairy wastes, landfill leachate, and the restoration of eutrophied surface waters.

The common objective in these applications is the removal of nutrients and degradable carbon in the water by the various components of the wetland system.[39] The components of a wetland ecosystem include (1) water, (2) sediment and substrate, which allow vegetation to become established and to obtain nutrients, (3) animals, especially invertebrates which process detritus and serve to maintain the steady flow of nutrients, (4) decomposers, and (5) vegetation, including submergent plants, floating leaved plants, and herbaceous and woody emergent species.[42] Aquatic organisms, such as algae, bacteria and higher plants, as well as animal life, consume the nutrients, minerals, and metals that are contained in municipal and industrial wastewaters, stormwater, and agricultural runoff.[41] The responses of the natural environment (i.e., vegetation, soil, microorganisms, and to a limited extent, higher animal life) to the waste stream provide the treatment.

Advantages of natural treatment systems include fewer operating personnel, lower energy consumption, and less sludge production. Important hydrologic factors for the design of wetland treatment systems include hydroperiod, hydraulic loading rate, hydraulic residence time, infiltration capacity, evapotranspiration, and overall water balance.[39]

Plant uptake of phosphorus can be significant (on the order of 1.1 kilogram per hectare per day) but most is cycled annually unless plant harvesting occurs.[39] Whether to include harvesting of vegetation in the operating plan is of considerable importance in system design and performance. Phosphorus removal is more difficult to predict in a non-harvested system. Phosphorus is recycled if plant tissue is not removed from the system when it ceases productivity.

Soil adsorption also is a major long-term phosphorus removal mechanism; however, most soils have a finite capacity for phosphorus adsorption without the addition of chemicals. The major sink for phosphorus in most wetlands is the soil. Phosphorus may be buried in organic forms such as peat, or chemically adsorbed in complexed forms with aluminum, iron, or calcium. Wetland soil types vary widely in terms of phosphorus adsorption capacity.

On an annual average basis, phosphorus behaves more conservatively than nitrogen in wetland treatment systems because of the lack of an atmospheric sink or source. Short-term, phosphorus is a highly mobile element in wetlands and is involved in many biological and soil/water interchanges. Dissolved phosphorus may be present in organic or inorganic forms and is readily transferred between the two forms. Plant uptake of dissolved inorganic phosphorus is rapid and, upon decay of plant tissues, phosphorus may be quickly recycled to the water column or deposited in sediments.[39]

The Water Environment Federation (WEF) defines wetlands as "land where the water surface is at or above the ground surface for a long enough period each year to maintain saturated soil conditions and growth of related vegetation."[39] Wetlands are usually naturally occurring; however, they can be constructed on upland areas. Constructed wetlands usually are considered by regulators to be a part of the treatment process so that regulatory controls apply to the effluent rather than the influent. Natural wetlands, on the other hand, are usually considered to be "waters of the state" or "waters of the United States" so that in some instances, wastewater applied to wetlands must not exceed assimilative capacities or a violation of water quality standards may occur.[39]

The Clean Water Act only authorizes construction grants for treatment facilities that, when constructed, do not degrade the wetland environment. Under this regulation, the potential adverse impact of a project on the wetland has to be evaluated to determine whether (1) water quality standards in the wetland are met and (2) alterations to the wetland are minimized. Primary responsibility for wetland permitting lies with the U.S. Army Corps of Engineers through the dredge and fill permit program under Section 404 of the 1977 Clean Water Act (13 United States Code S.1344).

Basis of Evaluation

The proposed wetland treatment technology can be applied at the basin, subbasin, farm, and point source scales. The systems have been evaluated assuming no bypassing of flows (minimum detention time of 2 days at peak flow) and average annual phosphorus loads to determine the required effective treatment area. Conceptual designs completed at the basin scale (STA) by Burns & McDonnell[9] and at the farm scale (FTA) by the District[44] provide detailed phosphorus load, hydraulic load, and effective treatment area calculations as well as cost estimates. This information formed the basis for this analysis.

In the STA conceptual design report, Burns & McDonnell developed a deterministic model for estimating phosphorus removal efficiency in the STAs based upon the data from WCA 2A. The model reduces estimates of long-term phosphorus removal to a direct relationship between total phosphorus concentration and rate of phosphorus deposition. That relationship is defined in terms of an apparent long-term average settling rate, in which the rate of phosphorus deposition is directly dependent on the total phosphorus concentration. This deterministic model, when applied using data from WCA 2A, indicates an apparent long-term average settling rate of 8 meters per year (m/yr). This value was used as the basis for sizing the STAs.[37]

Data collected for WCA 2A over a 9.75-year period, ending September 30, 1988, was used in the model. WCA 2A has an estimated effective area of 13,300 acres. Estimates of the long-term average phosphorus removal performance in the wetlands were calculated by the following equation:[37]

$$R = K\,A\,C$$

where: R = removal rate, gm/yr

K = apparent settling velocity, m/yr

C = total phosphorus concentration, gm/m^3

A = effective surface area, m^3

Application of this model to the hydraulic and phosphorus loading anticipated to be received by the STA wetlands yielded average projected uptake rates ranging from 0.567 to 0.938 grams per square meter per year (gm/m^2/year).[37] Total wetland treatment acreage needed for the four STAs, as estimated by the model, was 31,975 acres. The required effective area of each wetland system includes consideration of a 20 percent reduction in flow due to implementation of BMPs. While performance of the STAs in nutrient removal will not be sensitive to temporal variations in runoff reductions due to implementation of BMPs, the required conveyance capacity of the wetlands will be influenced. The wetlands are designed to accommodate all runoff from the EAA without hydraulic bypass. The wetlands must accommodate peak daily discharges and are designed not to impact adversely the design and operation of the Central and South Florida Flood Control Project.[37]

It was concluded in the Burns & McDonnell report that the hydraulic loading rates for the wetland systems, as conceptually designed, are representative of those experienced in that portion of WCA 2A which effectively acts as a stormwater treatment area in reducing phosphorus concentrations to a long-term, flow-weighted average of 0.05 mg/l.[37]

A review of 50 wetland treatment systems of various types and conditions in North America indicates that phosphorus removal efficiencies in the range of 30 to 50 percent are common.[39] Systems with influent phosphorus concentrations below 3 mg/l were found to have a non-flow weighted average removal efficiency of 47 percent, within a range of -56 to 96 percent.[39] Phosphorus removal efficiencies in WCA 1, WCA 2A, and WCA 3A, south of the EAA, were reported to be 48, 64, and 80 percent, respectively.

A summary of data collected during an intensive 3-year study at the 300-acre Orange County, Florida, Eastern Service Area Wetland Treatment System is presented below. Influent refers to water entering the wetland system. Midpoint refers to the location at which water from the first half of the system is collected and redistributed to the second half of the wetland treatment system. Discharge refers to water passing through the effluent outfall from the system.

Phosphorus Removal Summary--Eastern Service Area Wetland Treatment System, Orange County, Florida

Year	Total phosphorus concentration, mg/l			Phosphorus load, $gm/m^2/yr$		Percent removal efficiency
	Influent	Midpoint	Discharge	Influent	Discharge	
1	0.50	0.06	0.04	0.37	0.07	81
2	0.21	0.09	0.08	0.47	0.09	81
3	0.10	0.07	0.09	0.15	0.11	27

The Orange County system shows consistent effluent quality but inconsistent phosphorus removal efficiency. It should be noted that removal efficiency was computed on a mass basis using data collected at the midpoint of the treatment system. The second half of the treatment system reduced the phosphorus concentration in the first year but contributed phosphorus in the third year. This is an example of the capricious nature of phosphorus behavior in wetland systems when very low concentrations are present. The data indicate that wetlands can produce low phosphorus concentrations, but performance varies from one system to another. Total phosphorus removal efficiency of wetland systems increases with higher input concentrations; likewise, it decreases and becomes less predictable as concentrations decrease.

Of the systems reviewed in this evaluation, WCA 1, WCA 2A, and WCA 3A most closely approximate the wetland treatment systems that would be constructed to treat flows from the EAA. Therefore, performance data from these systems were used as the basis for evaluating the applicability of wetland treatment systems for satisfying the goals of the SWIM Plan. The data suggest that 75 percent removal efficiency on a long-term basis, with a great degree of confidence, cannot be predicted given the very low influent and effluent phosphorus concentrations involved.

The hydraulic loading of each treatment area is constrained by the need to control depths, velocities, and hydraulic retention times consistent with the need to maintain targeted plant species within each cell of the treatment area; promote development of the microbial communities in the litter zone; and to provide sufficient contact time for nutrient uptake.[37]

The wetland treatment systems are designed to simulate flow characteristics of the marshes that existed prior to the establishment of the EAA.[38] Each wetland system is envisioned to comprise two types of treatment cells:

1. Flow-way cells, composed of dense growths of rooted, emergent macrophytes. The flow-way cells receive inflows and are intended to remove most of the phosphorus. The average total phosphorus concentration discharging from the flow-way cells is estimated to be 0.07 mg/l.

2. Polishing cells, which are anticipated to be either algal-based vegetative communities (primarily periphyton), with sparse rooted emergent and rooted macrophytes; or a mixed-marsh community comprising rooted, emergent macrophytes. The polishing cells are intended to reduce the phosphorus concentration from 0.07 mg/l to the targeted 0.05 mg/l. Of the total 32,000 acres of wetland area needed, approximately 9,600 acres, or 30 percent, are to be developed as polishing cells.[37]

During our review of the conceptual design report for the STAs, we did not identify any analytical basis for sizing of the polishing cells. It is our understanding that ongoing work related to permitting and design of the STAs will include further evaluation of the polishing wells.

As currently configured, the wetland systems include physical separation between the flow-way cells and the polishing cells. This separation will allow hydraulic bypass of the polishing cell to permit discharge through the flow-way cell, if necessary, as well as hydraulic bypass of the flow-way cell to permit direct flow to the polishing cell for stage maintenance in the event of drought conditions and for initial establishment or subsequent reestablishment, if necessary.[37]

Table 3-12 summarizes the flows, land area requirements, and capital costs used for the evaluation of the constructed wetland treatment technology at the different phosphorus removal levels and scales of application in the EAA. The land area requirements and capital cost estimates for the basin and farm scale facilities (STAs and FTAs) at the 75 percent phosphorus removal level are the same as those presented in the conceptual design reports discussed previously. Land area requirements and capital cost estimates for the other scales of application were calculated in a manner consistent with the procedures used in the conceptual design of the STAs. All cost estimates taken or derived from the conceptual design reports were adjusted to 1992 dollars.

It should be noted that the flows, land areas, and capital costs are the same for the 75 and 50 percent phosphorus removal levels, resulting from concern over the ability of the wetlands to consistently achieve 75 percent phosphorus removal on a long-term basis. The wetlands have a much higher capability to achieve 50 percent phosphorus removal than 75 percent and, therefore, according to the methodology described in Chapter 2, the land area requirements were not reduced for evaluation at the 50 percent removal level. At the 25 percent removal level, however, reduced land area requirements could be realized since it is highly probable that 50 percent of the phosphorus can be removed by the wetlands treatment system and less flow must be treated to accomplish the 25 percent goal.

Evaluation Results

Presented in Exhibit 3-12 are the ratings given to the wetland treatment technology at the various scales of application and phosphorus removal levels. The technology received its highest ratings at the drainage basin and subbasin scales, and in all categories received higher ratings in the 25 and 50 percent removal categories than in the 75 percent category, due to relative performance reliability.

Table 3-12 Basis of Evaluation for Wetlands

Parameter	Scale of application							
	Basin		Subbasin		Farm		Point source	
	Scale unit	Total EAA	Scale unit	Total EAA	Scale unit	Total EAA	Scale unit	Total EAA
Peak flow capacity, mgd								
25 percent P removal	1,694	6,776	169	6,776	39	6,776	20	140
50 percent P removal	2,330	9,320	233	9,320	54	9,320	20	140
75 percent P removal	2,330	9,320	233	9,320	54	9,320	20	140
Land area, acres								
25 percent P removal	5,200	20,800	520	20,800	85	14,705	285	1,995
50 percent P removal	8,000	32,000	800	32,000	154	26,642	512	3,584
75 percent P removal	8,000	32,000	800	32,000	154	26,642	512	3,584
Capital cost,[a] million dollars								
25 percent P removal	58	234	6.0	238	1.7	302	3.6	25
50 percent P removal	83	333	8.9	356	2.4	409	5.6	39
75 percent P removal	83	333	8.9	356	2.4	409	5.6	39

[a] Costs derived from the STA and FTA conceptual design reports and adjusted to 1992 dollars.

Exhibit 3-12 Phase I Evaluation Ratings for Wetlands

Criterion	Criterion weighting[a]	Scale of application/level of phosphorus reduction[b]											
		Drainage basin			Subbasin			Individual farm			Point source		
		25	50	75	25	50	75	25	50	75	25	50	75
Phosphorus removal capability	3	10/30	10/30	6/18	10/30	10/30	6/18	10/30	10/30	6/18	10/30	10/30	6/18
Implementation schedule	2	7/14	7/14	7/14	7/14	7/14	7/14	6/12	6/12	6/12	7/14	7/14	7/14
Hydroperiod impact	2	7/14	7/14	7/14	7/14	7/14	7/14	6/12	6/12	6/12	6/12	6/12	6/12
Impact on C&SF Project	2	8/16	8/16	8/16	8/16	8/16	8/16	8/16	8/16	8/16	8/16	8/16	8/16
Permitting requirements	2	8/16	8/16	8/16	7/14	7/14	7/14	6/12	6/12	6/12	4/8	4/8	4/8
Previous application of technology	2	10/20	9/18	7/14	10/20	9/18	7/14	10/20	9/18	7/14	10/20	9/18	7/14
Capital cost	1	5/5	5/5	5/5	5/5	5/5	5/5	5/5	5/5	5/5	5/5	5/5	5/5
O&M requirements	1	8/8	8/8	8/8	8/8	8/8	8/8	7/7	7/7	7/7	8/8	8/8	8/8
Economic impacts	1	8/8	6/6	6/6	8/8	6/6	6/6	8/8	7/7	7/7	8/8	8/8	8/8
Total		131	127	111	129	125	109	122	119	103	121	119	103

[a] Criteria directly related to satisfying provisions of SWIM Plan receive a weighting of 2 or 3; all other criteria receive a weighting of 1.
[b] Phosphorus reduction levels of 25, 50 and 75 percent of the influent phosphorus estimated for each scale of application.

Water quality data taken from WCA 3A indicate that 75 percent phosphorus removal may be possible depending on influent concentration. In contrast, examination of water quality data from WCA 1 and WCA 2A and other wetland systems indicate that it is probably optimistic to expect consistent 75 percent removal. Data from many constructed and natural wetland treatment systems, however, provide excellent assurance that 50 percent removal is achievable, provided that the system is adequately designed and operated.

It is anticipated that the wetland treatment system will have a positive impact on hydroperiod in the Everglades. Hydroperiod benefits with the smaller-scale systems will be reduced because of the stormwater detention capabilities of wetlands. This alternative will not require significant changes to the Central and South Florida Flood Control Project. Wetlands permitting will require Corps of Engineers, FDER, and District permits.

Wetlands construction is implementable by 1997 if an aggressive schedule is followed. Project completion is somewhat more difficult at the subbasin and farm scales because of the larger number of facilities that need to be sited, designed, permitted, and constructed. Another critical factor in implementing this alternative successfully is the establishment of the desired wetland vegetation in sufficient size and density. Planting of specific types of vegetation versus volunteer growth should be explored in more detail in future evaluations of this technology.

Discussion of Evaluation

Wetlands envisioned for this project are characterized by submerged or emergent soft-stemmed herbaceous plants. Wetland treatment systems have been proven to provide some of the highest attainable levels of nutrient (nitrogen and phosphorus) removal from wastewater.[43]

Phosphorus removal efficiency varies widely in natural and constructed wetland treatment systems depending upon a complex relationship between soils, hydrology, vegetative community, chemistry, climate, concentration, and the specific fractionation of TP in the influent.[39] Based upon the conceptual designs of the STAs and FTAs, as well as operational data from the WCAs and other systems throughout the United States, wetlands treatment can provide significant phosphorus reductions at all scales of application in the EAA. Removal of 75 percent at the very low concentrations considered here may be optimistic. However, 50 percent removal should be achievable on a consistent, long-term basis. If used in conjunction with other phosphorus reduction measures, such as BMPs or pretreatment processes, wetlands treatment can be a meaningful component of a treatment system designed to meet the objectives of the District's SWIM Plan.

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MANAGED WETLANDS

The STAs currently proposed in the District's SWIM Plan are designed to be operated as unmanaged wetland systems without any form of pretreatment or harvesting to enhance performance. The managed wetlands technology is intended as an enhanced approach to wetlands treatment involving pretreatment of the influent flow to allow the natural marsh areas to reduce phosphorus concentrations to lower levels than might otherwise be achieved.

Overview of Technology

In this evaluation, the managed wetlands technology includes three treatment processes: chemical precipitation, overland flow, and shallow marsh wetlands. The first two treatment elements have the capacity to reduce influent phosphorus levels to enable the wetlands system to meet treatment goals reliably. Phosphorus removals in excess of 90 percent and residual phosphorus concentrations of less than 0.05 mg/l are achievable.[46]

The initial unit process in the managed wetland treatment system would be chemical addition and rapid mixing. A pump chemical feed system would be followed by a distribution channel where flocculation would occur. The distribution channel, which would be sized to prevent sedimentation, would lead to the overland flow system. Overland flow treatment cells would be provided to trap settleable solids and to allow for phosphorus to be removed from the treatment system through harvesting of vegetation. The overland flow area would also serve to distribute flows to a shallow marsh system, similar to the STAs and FTAs discussed previously.

Chemical Addition. Chemical treatment involves the use of conventional water and wastewater treatment equipment for precipitation of soluble phosphorus. Chemical precipitation has been used for phosphorus removal from wastewater for many years.[46] Recently it has been applied to remove phosphorus to very low levels (5 to 30 ppb) in tributaries to reservoirs and lakes in Germany.[47] It has also been used to treat urban stormwater runoff entering lakes in Orlando, Florida to control eutrophication.

In this application, a relatively small dosage of chemical, such as an iron salt, would be added to the influent water to precipitate a portion of the soluble phosphorus. Sufficient mixing would be provided to promote formation of floc in a distribution channel for sedimentation on the overland flow treatment slopes. A small concrete or lined earthen basin with mechanical mixers would be used for mixing the chemical with the water to be treated. Detention time in the basin would be on the order of 30 seconds at design flow.

Overland Flow. Overland flow is routinely implemented for the treatment of municipal and industrial process wastewater effluent streams. The overland flow process was developed to overcome the limitations to land treatment created by soils of low permeability.

In overland flow treatment, wastewater applied to the top of a graded slope flows in a thin film over a vegetated surface and is collected at the bottom of the slope. Distribution of the water can be accomplished by surface methods, low-pressure nozzles, or sprinklers. A typical midrange application rate for an overland flow system treating wastewater in Florida is about 16 inches per week.

Typical slope length is 150 feet to 600 feet at a grade of 1 to 2 percent. Reduction of various suspended and dissolved constituents occurs along the slope by physical, chemical, and biological means, primarily in the organic mat on the soil surface. A recirculation system is generally needed to sustain vegetation on the slopes during extended dry periods.

The major mechanisms responsible for phosphorus removal by overland flow include sorption on soil clay colloids; precipitation as insoluble complexes of calcium, iron or aluminum; and plant uptake. When low-permeability soils are present near the ground surface, as is the case for most overland flow systems, much of the applied water flows over the surface and does not come into contact with the soil matrix and the phosphorus adsorption sites. Consequently, phosphorus removal in overland flow systems is generally on the order of 50 percent or less.

In the managed wetland technology, the overland flow process would serve as a high rate sedimentation/filtration step following chemical addition. Hydraulic loading to the system would be much higher than for typical wastewater applications. An application rate on the order of 60 inches per week at average day flow is envisioned. The primary functions of the overland flow system would be to trap settleable solids and to distribute sheet flow evenly to the wetlands. In so doing, phosphorus would be taken up by vegetation and would be reduced agronomically in the soil matrix. Sections of the overland flow area would be operated alternately to allow for harvesting of grass and drying of solids that would be deposited on the treatment slopes.

Wetlands. The final treatment process is a shallow marsh wetlands, similar to that proposed for the STAs and FTAs. The wetland treatment area would be sized on the basis of annual phosphorus loading and would accept peak flows hydraulically to avoid bypassing. Inflows to the wetlands would be evenly distributed after passing through the overland flow system and influent phosphorus concentrations would be reduced as a result of pretreatment. The lower influent TP concentration resulting from pretreatment should result in a consistently lower effluent TP concentration from the marsh in this technology than would be expected from the STAs or FTAs.

Basis of Evaluation

The concept of the managed wetland treatment technology is to provide pretreatment of the influent EAA drainage water so that the shallow marsh wetlands can reliably achieve the 0.05 mg/l TP objective on a long-term basis. Consistent with this approach, the chemical treatment and overland flow systems were sized to achieve a reduction in TP concentration from 0.15 mg/l to 0.10 mg/l. The wetland system was sized to reduce TP concentration from 0.10 mg/l to 0.05 mg/l.

Together, the pretreatment processes have the capability to reduce TP concentrations to below the 0.10 mg/l pretreatment goal. This means that they can be sized to treat only a portion of the flow. For the purpose of this Phase I evaluation, it was assumed that the chemical treatment and overland flow systems could achieve an effluent TP concentration of 0.05 mg/l on a consistent basis. Using the information presented on Figure 2-1, the pretreatment system would need to have a design treatment capacity of 550 mgd. Flows in excess of 550 mgd would be bypassed around the pretreatment units and would be blended with the treated flow prior to being introduced into the wetlands. The blended flow would be expected to have a TP concentration of 0.10 mg/l or less depending on actual influent flow rate.

Because the overland flow component of the pretreatment system must remain wet, at least periodically, even during prolonged dry weather periods, it was assumed that a flow recirculation system would be required. Flow recirculation pumps were sized to deliver half the average day flow rate. This additional pumping capacity added significantly to the cost of the pretreatment system, particularly at the smaller scales of application.

Wetland treatment areas were sized on the basis of annual phosphorus loading according to the methodology used in the conceptual design of the STAs. The wetlands were also sized to provide a minimum 2-day detention time at peak flow assuming a maximum water depth of 2 feet. In some cases, particularly at the 50 and 25 percent phosphorus removal levels, the minimum detention time criterion required more acreage than did the annual phosphorus loading using a phosphorus settling rate of 8 meters per year. The overland flow system was assumed to be located immediately adjacent to the wetland treatment area, forming a strip along the upstream edge to assist in the distribution of flow into the marsh.

At the 75 percent removal level, it was assumed that the full wetland treatment area currently proposed for the STAs and FTAs would be required, even with pretreatment of the influent flow to 0.10 mg/l TP. This assumption was made to increase the level of confidence that the wetlands could produce an effluent TP concentration of 0.05 mg/l or less on a consistent, long-term basis.

At the 50 percent phosphorus removal level, approximately one-third less land would be required for the wetlands treatment area. Assuming that all of the influent flow is pretreated to 0.10 mg/l, the wetlands would only have to provide an additional 25 percent removal to achieve the 0.075 mg/l treatment objective. Since the treatment system is capable of reliably achieving an effluent TP concentration of 0.05 mg/l, downsizing of the wetlands treatment area at the 50 percent removal level is appropriate.

At the 25 percent phosphorus removal level, either the pretreatment processes or the wetland treatment areas could be eliminated from the system. In this analysis, it was assumed that pre-treatment would not be provided and that the wetlands would provide the necessary treatment on its own. Land area requirements would be essentially the same as for the 50 percent removal level. At the 25 percent removal level, the managed wetland system would be similar to the wetland system discussed in the previous section of this chapter.

Table 3-13 summarizes the design flows, land area requirements, and capital cost estimates used as the basis of evaluation for the managed wetland treatment technology. Cost estimates for the wet-lands treatment areas were based on estimates contained in the STA and FTA conceptual design reports. Cost estimates for chemical feed and mixing equipment were derived from estimates presented previously in this chapter for the chemical treatment technology. Capital costs for overland flow treatment were based on an aggregate system cost of $8,000 per acre of treatment slope.

Evaluation Results

Presented in Exhibit 3-13 are the Phase I evaluation ratings for the managed wetlands treatment technology. A properly designed and operated combination of chemical precipitation, overland flow, and wetlands treatment is capable of meeting the treatment objectives of the SWIM Plan at all scales of application in the EAA. Lower ratings were given at the individual farm scale because of greater

Table 3-13 Basis of Evaluation for Managed Wetlands

Parameter	Scale of application							
	Basin		Subbasin		Farm		Point source	
	Scale unit	Total EAA	Scale unit	Total EAA	Scale unit	Total EAA	Scale unit	Total EAA
Design flow for chemical treatment and overland flow, mgd								
25 percent P removal	N/A[a]	N/A	N/A	N/A	N/A	N/A	N/A	N/A
50 percent P removal	555	2,220	55	2,220	3.2	554	10	70
75 percent P removal	555	2,220	55	2,220	3.2	554	10	70
Peak flow capacity for wetlands, mgd								
25 percent P removal	1,694	6,776	169	6,776	39	6,776	20	140
50 percent P removal	1,694	6,776	169	6,776	39	6,776	20	140
75 percent P removal	2,330	9,320	233	9,320	54	9,320	20	140
Total land area, acres								
25 percent P removal	5,720	22,880	572	22,880	93	16,090	314	2,200
50 percent P removal	5,720	22,880	572	22,880	93	16,090	314	2,200
75 percent P removal	8,800	35,200	880	35,320	169	29,240	563	3,940
Capital cost,[b] million dollars								
25 percent P removal	58	234	6.0	238	1.7	302	3.6	25
50 percent P removal	72	287	9.1	363	3.6	620	5.9	41
75 percent P removal	101	403	12.5	498	4.3	745	8.3	58

[a] Chemical treatment and overland flow not required at 25 percent P removal level.
[b] Wetlands costs derived from the conceptual design reports for the STAs and FTAs; all costs adjusted to 1992 dollars.

Exhibit 3-13 Phase I Evaluation Ratings for Managed Wetlands

Criterion	Criterion weighting[a]	Scale of application/level of phosphorus reduction[b]											
		Drainage basin			Subbasin			Individual farm			Point source		
		25	50	75	25	50	75	25	50	75	25	50	75
Phosphorus removal capability	3	10/30	10/30	10/30	10/30	10/30	10/30	9/27	7/21	5/15	10/30	9/27	8/24
Implementation schedule	2	7/14	7/14	7/14	7/14	7/14	7/14	6/12	6/12	6/12	7/14	7/14	7/14
Hydroperiod impact	2	7/14	7/14	7/14	7/14	7/14	7/14	6/12	6/12	6/12	6/12	6/12	6/12
Impact on C&SF Project	2	8/16	8/16	8/16	8/16	8/16	8/16	8/16	8/16	8/16	8/16	8/16	8/16
Permitting requirements	2	8/16	8/16	8/16	7/14	7/14	7/14	6/12	6/12	6/12	4/8	4/8	4/8
Previous application of technology	2	10/20	9/18	8/16	10/20	9/18	8/16	10/20	9/18	8/16	10/20	9/18	8/16
Capital cost	1	5/5	6/6	4/4	5/5	5/5	4/4	5/5	4/4	4/4	5/5	5/5	4/4
O&M requirements	1	6/6	5/5	5/5	6/6	5/5	5/5	5/5	4/4	4/4	6/6	5/5	5/5
Economic impacts	1	8/8	8/8	6/6	8/8	8/8	6/6	8/8	8/8	6/6	8/8	8/8	8/8
Total		129	127	121	127	124	119	117	107	97	119	113	107

[a] Criteria directly related to satisfying provisions of SWIM Plan receive a weighting of 2 or 3; all other criteria receive a weighting of 1.
[b] Phosphorus reduction levels of 25, 50 and 75 percent of the influent phosphorus estimated for each scale of application.

variations in flow and because of the increased O&M requirements associated with a large number of individual treatment facilities.

Hydroperiod impacts are expected to be positive, with increased sheet flow and limited equalization provided by the wetland portion of the system. Flood control is expected to be positive for the same reasons. Florida DER construction and operating permits would be required at all scales of application.

This technology has been successfully applied at full scale in water and wastewater treatment applications at flow rates equivalent to farm scale systems. The chemical and wetlands portions of the system have been applied successfully for stormwater treatment.

Capital costs are expected to be higher than the base case wetlands system because of the chemical feed and overland flow pretreatment processes. O&M requirements are also greater than the base case for the same reasons. Land area requirements are approximately the same as the base case at all scales of application.

Discussion of Evaluation

Managed wetland systems have the potential to reduce phosphorus concentrations in EAA drainage water to very low levels. These systems are designed and constructed to remove phosphorus and nitrogen efficiently. The consistency and longevity of the phosphorus removal capability is somewhat questionable from a land treatment standpoint. However, chemical addition to the influent will improve long-term treatment efficiency. It is not certain what dosage of chemicals applied to influent agricultural drainage water with a phosphorus concentration of 150 ppb would be required to effect significant precipitation of phosphorus. Ongoing research sponsored by the Florida Sugar Cane League to investigate the feasibility of chemical treatment in the EAA may help to define appropriate chemical dosages for this technology as well.

Applications at the farm and point source scales have demonstrated significant phosphorus removal capability. It is expected that at the larger scales of application, similar phosphorus removal capability could be demonstrated. At all scales of application, operation and maintenance, including sludge management, mowing, and slope maintenance, would be more intensive than for the base case wetlands system.

In summary, managed wetland treatment systems have potential for satisfying the phosphorus reduction goals of the District's SWIM Plan. However, to implement this option by 1997, an aggressive schedule will need to be followed to complete land acquisition, facilities design, and construction.

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DIRECT FILTRATION

Conventional water treatment generally involves chemical precipitation and separation of suspended solids. Typical processes include chemical feed, rapid mix, coagulation/flocculation, sedimentation and/or filtration. Conventional chemical precipitation has been used for phosphorus removal from wastewater for many years.[1] Recently it has been applied to remove phosphorus to very low levels in tributaries to reservoirs and lakes in Germany to control eutrophication.[48] In addition, operating data show that water treatment plants using chemical coagulants for turbidity removal also remove phosphorus to low levels.[49] Conventional water treatment technology has been suggested as a means of reducing phosphorus concentrations in discharges from the EAA and direct filtration is proposed as the most appropriate form of that technology for this evaluation.

Overview of Technology

Several chemicals, such as aluminum salts, ferric salts, and lime, have been used to form insoluble precipitates with dissolved inorganic and organic phosphorus. The use of lime as a chemical precipitant for phosphorus removal from wastewater has become unpopular in recent years because of the larger volume of sludge generated and the operation and maintenance (O&M) problems associated with the handling, storage, and feeding of lime.[13] Ferric salts and alum usually are used. To assist in the settling or separation of the insoluble phosphorus compounds, an organic coagulation aid is added to the water to promote particle size growth (coagulation/flocculation). If the total suspended solids (TSS) concentration of the water and the chemical dosages are not too high, the resultant coagulated/flocculated water will contain relatively few solids and may go directly to granular media filters for phosphorus and TSS removal (direct filtration). However, if the TSS concentration of the water or the mass of chemical solids precipitated is high, a sedimentation step may be necessary to remove these solids ahead of the filters to avoid rapid buildup of pressure drop and short filter runs.

Filters usually are required at the end of the treatment train to achieve very low levels of phosphorus in the treated effluent. Phosphorus removal to low levels is usually required in water reclamation and reuse projects in which secondary effluents are treated to achieve the required water quality. Operating data from pilot-and full-scale treatment systems indicate that phosphorus concentrations can be removed from 6 to 9 mg/l in secondary effluents to 0.03 to 0.3 mg/l (30 to 300 ppb) in final effluents.[1] Most of these systems use alum as the chemical precipitant and coagulant. Higher removal efficiencies are achieved at higher alum dosages. Surface overflow rates for sedimentation basins have ranged from 580 to 1,440 gallons per day per square foot (gpd/ft^2) and filtration rates have ranged from 2 to 5 gallons per minute per square foot (gpm/ft^2).

A more applicable example for comparison with treatment requirements in the EAA is the phosphorus elimination plant (PEP) at Wahnbach Estuary Reservoir located near Bonn, Germany, where a precipitation/coagulation/filtration process has been utilized since late 1977.[48] The PEP treats water from the main tributary to the reservoir. It consists of a pre-reservoir (equalization basin) with a volume of 500,000 cubic meters (130 million gallons) and a coagulation/filtration system with a maximum throughput of 5 cubic meters per second (113 mgd). Influent TP concentrations range from 60 to 210 ppb. The mean effluent TP concentration is 5 ppb. Ferric sulfate is used as the coagulant at a dosage which ranges from 4 to 10 mg/L. Maximum filtration rate is 15 meters per hour (6.4 gpm/ft^2).

Two other similar PEPs have been built in Berlin since the early 1980s.[48] These two plants, however, treat water with much higher phosphorus concentrations. In these plants, it was necessary to apply a sedimentation step prior to filtration. Due to the high concentration of organic phosphorus, the mean effluent TP concentration has been about 30 ppb.

Operating data from the City of Tampa's Hillsborough River Water Treatment Plant indicate that chemical coagulation, flocculation, sedimentation, and filtration reduced total phosphorus from a mean of 0.23 mg/l to less than the city's detection limit of 0.1 mg/l in 1991.[13] Alum was the primary chemical coagulant for turbidity removal during this period. Since the beginning of 1992, ferric sulfate has replaced alum as the primary coagulant. Phosphorus removal efficiencies for the past 7 months have been similar to those experienced with alum.

Based on the above discussions, it is clear that conventional water treatment processes are capable of removing phosphorus concentrations in water from the EAA to below 50 ppb. The technology is readily available and has been applied successfully at full scale for treatment of stormwater and agricultural drainage as well as raw water supplies.

Basis of Evaluation

The TSS concentration of drainage water from the EAA is not well characterized. Therefore, it is not totally clear whether sedimentation would be required ahead of the filters. Since phosphorus concentrations are relatively low, it is assumed that TSS levels are low also and that sedimentation tanks would not be necessary ahead of the filters. The treatment system would be designed and operated as a direct filtration plant with chemical feed (ferric sulfate, caustic, and polymer), rapid mix, flocculation, and filtration. Backwash water would be routed to settling ponds. Supernatant would be returned to the head of the filter plant. The solids would be removed periodically and stored in sludge lagoons. Every several years, solids in the lagoons would be removed, allowed to dry, and land applied.

Based on the TP removal data cited in the literature from similar previous applications of conventional water treatment using direct filtration, it is reasonable to assume that the technology is capable of achieving effluent TP concentrations of 0.01 mg/l (10 ppb) if properly designed and operated. Using the relationships illustrated on Figure 2-1 in Chapter 2, a direct filtration plant with a design flow capacity of 700 mgd would be required at the basin scale to remove 75 percent of the influent TP on an annual mass basis. Plant capacities of 380 mgd and 180 mgd would be required at the basin scale to achieve 50 and 25 percent TP removals, respectively. Proportionally lower plant capacities would be required at the smaller scales of application.

The sizing of treatment units is based on detention times and filtration rates. Based on general water treatment plant design guidelines,[50] a rapid mixing time of 30 seconds, a flocculation time of

15 minutes, a filtration surface loading rate of 5 gpm/ft^2 at the maximum design flow rate, and a ferric sulfate dosage of 10 mg/l were assumed for this evaluation. Pilot plant studies may be conducted to optimize these design parameters and to provide operating data before full-scale implementation. Concrete gravity filters with dual media, consisting of anthracite and sand, were assumed for costing purposes.

The design flows, filter areas, total land areas, and capital costs used as the basis of evaluation for direct filtration treatment at the various scales of application in the EAA are summarized in Table 3-14. Land area requirements are very low compared with most of the other technologies being considered in this evaluation.

Capital costs for treatment units were prepared using 1978 water treatment plant process cost information published by the U.S. Environmental Protection Agency. The costs were adjusted to 1992 dollars and then compared with contractor bid data from recent Brown and Caldwell projects of similar size and type. Where appropriate, refinements to the initial estimates were made. Additional allocations were made for site development, utilities, and process electrical and instrumentation costs which were not included in the published treatment unit costs. Sludge lagoons were assumed to be lined with a single geosynthetic liner. However, no dewatering costs were allocated under the assumption that the lagoons would be constructed partially above grade to allow for gravity return of supernatant to the plant influent canal. The capital costs presented in Table 3-14 clearly show that the economics of direct filtration treatment favor the large, basin scale projects.

Evaluation Results

Presented in Exhibit 3-14 are the Phase I evaluation ratings given to direct filtration at the various scales of application and phosphorus removal levels. The technology received its highest ratings at the point source scale and its lowest ratings at the individual farm scale. The technology is proven and well established for TP removal to very low concentrations. However, variations in influent characteristics can result in deterioration of effluent quality if strict process control is not maintained. Consequently, the technology received slightly higher ratings at the lower phosphorus removal levels.

Discussions of Evaluation Results

Direct filtration following chemical precipitation has been successfully applied to treat stormwater and agricultural drainage and to remove phosphorus to low levels. The design parameters are readily available and the technology can be implemented quickly, provided materials and labor are available.

Land area requirements for direct filtration treatment were determined to be very low compared to the base case wetlands alternative (STAs). Capital costs at the basin scale were found to be about the same or slightly lower than the base case STAs. At the smaller scales, however, the capital cost associated with direct filtration rises sharply and the technology received substantially lower ratings when compared against the capital cost of the STAs and FTAs.

Table 3-14 Basis of Evaluation for Direct Filtration

Parameter	Scale of application							
	Basin		Subbasin		Farm		Point source	
	Scale unit	Total EAA	Scale unit	Total EAA	Scale unit	Total EAA	Scale unit	Total EAA
Design flow, mgd								
25 percent P removal	180	720	18	720	3	519	5	35
50 percent P removal	380	1,520	38	1,520	6	1,038	10	70
75 percent P removal	700	2,800	70	2,800	11	1,938	15	105
Filter area, thousand sq. ft.								
25 percent P removal	25	100	2.5	100	0.4	73	0.7	5
50 percent P removal	53	212	5.3	212	0.8	144	1.4	10
75 percent P removal	97	388	9.7	388	1.6	270	2.1	15
Land area, acres								
25 percent P removal	23	92	3	120	1.0	173	1.1	8
50 percent P removal	47	168	6	240	1.2	208	1.9	13
75 percent P removal	70	280	10	400	2.0	346	2.7	19
Capital cost,[a] million dollars								
25 percent P removal	54	216	18	736	8	1,349	10	69
50 percent P removal	80	320	24	960	10	1,747	13	93
75 percent P removal	105	420	32	1,280	14	2,422	16	112

[a] 1992 dollars.

Exhibit 3-14 Phase I Evaluation Ratings for Direct Filtration

Criterion	Criterion weighting[a]	Scale of application/level of phosphorus reduction[b]											
		Drainage basin			Subbasin			Individual farm			Point source		
		25	50	75	25	50	75	25	50	75	25	50	75
Phosphorus removal capability	3	10/30	9/27	8/24	10/30	9/27	8/24	9/27	7/21	5/15	10/30	9/27	8/24
Implementation schedule	2	9/18	9/18	9/18	8/16	8/16	8/16	7/14	7/14	7/14	9/18	9/18	9/18
Hydroperiod impact	2	5/10	5/10	5/10	5/10	5/10	5/10	5/10	5/10	5/10	5/10	5/10	5/10
Impact on C&SF Project	2	7/14	7/14	7/14	7/14	7/14	7/14	7/14	7/14	7/14	7/14	7/14	7/14
Permitting requirements	2	4/8	4/8	4/8	4/8	4/8	4/8	3/6	3/6	3/6	5/10	5/10	5/10
Previous application of technology	2	9/18	9/18	9/18	9/18	9/18	9/18	9/18	9/18	9/18	9/18	9/18	9/18
Capital cost	1	5/5	6/6	5/5	4/4	4/4	3/3	3/3	3/3	2/2	3/3	3/3	3/3
O&M requirements	1	5/5	5/5	5/5	4/4	4/4	4/4	2/2	2/2	2/2	5/5	5/5	5/5
Economic impacts	1	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10
Total		118	116	112	114	111	107	104	98	91	118	115	112

[a] Criteria directly related to satisfying provisions of SWIM Plan receive a weighting of 2 or 3; all other criteria receive a weighting of 1.
[b] Phosphorus reduction levels of 25, 50 and 75 percent of the influent phosphorus estimated for each scale of application.

There should be no significant impact on hydroperiod in the Everglades and operational impacts on the Central and South Florida Flood Control Project should be minor. It is assumed that plants at the basin, subbasin and point source scales will require NPDES permits, while farm scale projects will require only operating permits.

In comparison with chemical treatment using sedimentation, the direct filtration technology would be expected to use less chemicals because the large floc required for sedimentation is not necessary for filtration. Therefore, sludge production rates would be reduced significantly. The use of less chemicals also would cause less change in the chemistry of the water, and the potential for adverse effect on the biological community in the Everglades would be decreased.

In summary, direct filtration following chemical treatment is a potentially promising technology for the removal of phosphorus from EAA drainage water. It has a history of successful performance, requires little land, and should not be difficult to permit. Economics strongly favor application of the technology to large, basin scale projects however. Application for some point source discharges could also be feasible, but application at the subbasin and farm scales would appear to be prohibitively costly.

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BARGE TREATMENT

The Cherith Group (Cherith) has proposed a unique method of removing phosphorus from EAA drainage water. The proposed system consists of floating treatment units (barges) which could be moved to points in the District canal system where treatment is most needed. Water would be pumped from the canal through a proprietary on-board treatment system, which would remove the phosphorus. Treated water would be returned to the canal.

Overview of Technology

The barge treatment units are proprietary; therefore, we do not know the exact mechanism by which phosphorus is removed. Cherith personnel have indicated that the treatment rate is expected to be about 1 million gallons per hour per barge. The water is pumped to the treatment unit by an air-lift pump.

The treatment units provide seven stages of treatment. Large solids (vegetation, etc.) are removed in the first stage and burned in on-board incinerators. Stages 2 through 7 provide passage of flow through successively smaller openings starting at 100 microns and decreasing to 1 micron. Physical straining obviously plays some part in removing particulate phosphorus. Cherith indicates some form of ion exchange appears to be responsible for removing dissolved phosphorus. Cherith indicates that the screen openings are created by a series of iron rods that are spaced closer together in successive stages. There is also an electrical (DC) component to the process. It is assumed that the electrical current promotes dissolving of the iron rods. The iron ions do not move far into solution, instead reacting with the phosphorus in the vicinity of the rods. Thus the phosphorus tends to be held closely to the rods and is removed from solution. Cherith indicates sludge volumes are small relative to sludge volumes of typical precipitation processes.

Calculations for sizing the internal process units are based on laboratory tests using one-liter treatment units. The influent phosphorus concentration was reduced from about 1 mg/l to 0.01 mg/l. Cherith indicates the treatment units will remove silica, heavy metals, bacteria, fungi, algae, cysts, parasites, mosquito larvae, and the pathogenic amoebae Naegleri-floweri.

Cherith proposes to remove the process components of the treatment units about every 30 days, replacing them with fresh materials. The exhausted materials would be shipped to Birmingham, Alabama for regeneration. Cherith claims that the phosphorus and organic content of the regeneration residue would make excellent fertilizer. However, the heavy metal content of the residue would have to be considered in any evaluation of the residue's fertilizer value.

The barges would be shallow hydrojet units which draw about 2 feet of water. Each barge would have a crew of 20 to provide operation 24 hours per day. No barges have been constructed to date and testing of the treatment units has not been accomplished outside the laboratory.

Cherith indicates the barges would be able to enter most of the canals. If the structure of the canal is such that the barge cannot move freely from one part to another, a barge would be dedicated to the isolated portion and left there.

During dry weather conditions, the barges would move up and down the canals, providing treatment. Stationery treatment units, in contrast, would not have the ability to treat water during low flow situations. During storm flow situations, the barges would be placed to intercept the maximum possible flow.

Each barge would cover a 20-mile stretch of canal. The barges would move at about 1 mile per hour (mph) while the treatment units are operating. The barges would move to staging areas at the end of 12-hour shifts to accommodate crew changes and to replenish fuel and other supplies.

Basis of Evaluation

We assumed that barge treatment would be applied only at the basin and subbasin scales and only on District canals. Application at the farm and point source scales is impractical. Because the discharge points at these smaller scales are not necessarily linked by common canals, one barge would be required for many individual discharge points. We believe that this requirement would make barge treatment prohibitively expensive at the farm and point source scales, even if smaller barges were used or if the barges were replaced by stationary treatment units.

Presented in Table 3-15 are the estimates of the number of barges and the capital and operating costs that were used in this evaluation. We assumed, theoretically, that the barge treatment units could achieve the same level of phosphorus removal from EAA drainage water as they achieved in Cherith's laboratory experiments. This was reported to be as high as 99 percent. Portions of the water in the canal would be bypassed around the barges. The treated water and bypass water streams would be blended to achieve the desired phosphorus removal. We also made the simplifying assumption that the barges would pump only untreated water and that no previously treated water (from an upstream barge) would be pumped through treatment units a second time.

We used cost information provided by Cherith and their consultant in developing our cost estimates. Cherith estimates the capital cost of providing 50 barges to be \$198 million. We used this figure in the following equation to determine the cost of barges for the various treatment scenarios:

$$CC_y = \$198{,}000{,}000 \left(\frac{Y}{50}\right)^{0.6} \tag{1}$$

Where: CC_y = capital cost of Y barges; and

Y = number of barges needed

Table 3-15 Basis of Evaluation for Barge Treatment

Parameter	Scale of application							
	Basin		Subbasin		Farm		Point source	
	Scale unit	Total EAA	Scale unit	Total EAA	Scale unit	Total EAA	Scale unit	Total EAA
Barges needed								
25 percent P removal	13.2	53	1.3	53	N/A[a]	N/A	N/A	N/A
50 percent P removal	15.5	62	1.5	61				
75 percent P removal	18.6	74	1.9	74				
Capital cost,[b] million dollars								
25 percent P removal	52.5	210	5.2	209				
50 percent P removal	57.5	230	5.7	229				
75 percent P removal	64.0	256	6.4	55				
Operating and maintenance cost,[b] million dollars per year								
25 percent P removal	40.3	161	4.0	159				
50 percent P removal	46.5	186	4.6	184				
75 percent P removal	55.3	221	5.5	219				

[a] Technology not evaluated at the farm and point source scales of application.
[b] 1992 dollars.

We assumed there would be four staging areas per basin and used Cherith's estimate of $2 million per staging area in our calculations.

We also used Cherith's operation and maintenance cost estimates of $2.8 million per year per barge and $3 million per year per staging area in developing our costs.

Evaluation Results

The Phase I evaluation ratings for barge treatment are presented in Exhibit 3-15. The technology received generally low results, reflecting our concern about its lack of previous application, operability, and very high projected operating costs.

Discussion of Evaluation Results

The barge treatment technology evaluated here is very much in the developmental stage. Projected phosphorus removals have been based on laboratory test results. A pilot- or full-scale demonstration of this technology, over an appropriate time span (several months), is needed to adequately assess its reliability.

Furthermore, the treatment unit appears to have considerable potential for fouling. The openings in the final treatment stages are very small (1 micron). These openings are likely to plug rapidly, particularly if the air-lift feed pumps convey any colloidal sediments. We believe the treatment units must be protected with granular media filters located between the solids removal step and the treatment units themselves. It is not known whether this protection is being considered.

The barge treatment scheme may need a very sophisticated management system to realize its full treatment potential. Specifically, the barges must be located so that downstream barges do not waste their capacity processing already-treated effluent from upstream barges. Land-based treatment units would not have to consider this potential problem. The barge technology has the advantage of being able to remove phosphorus during dry weather and low flow conditions. However, storage volume in the canals, relative to the volume of runoff that must be treated during major storm events, is small. Therefore, the actual value of this advantage is questionable.

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Exhibit 3-15 Phase I Evaluation Ratings for Barge Treatment

Criterion	Criterion weighting[a]	Scale of application/level of phosphorus reduction[b]											
		Drainage basin			Subbasin			Individual farm			Point source		
		25	50	75	25	50	75	25	50	75	25	50	75
Phosphorus removal capability	3	2/6	1/3	1/3	2/6	1/3	1/3	N/A	N/A	N/A	N/A	N/A	N/A
Implementation schedule	2	3/6	2/4	1/2	3/6	2/4	1/2						
Hydroperiod impact	2	6/12	6/12	6/12	6/12	6/12	6/12						
Impact on C&SF Project	2	5/10	5/10	5/10	5/10	5/10	5/10						
Permitting requirements	2	3/6	3/6	3/6	3/6	3/6	3/6						
Previous application of technology	2	1/2	1/2	1/2	1/2	1/2	1/2						
Capital cost	1	6/6	7/7	7/7	6/6	7/7	7/7						
O&M requirements	1	2/2	2/2	2/2	2/2	2/2	2/2						
Economic impacts	1	10/10	10/10	10/10	10/10	10/10	10/10						
Total		60	56	54	60	56	54						

[a] Criteria directly related to satisfying provisions of SWIM Plan receive a weighting of 2 or 3; all other criteria receive a weighting of 1.
[b] Phosphorus reduction levels of 25, 50 and 75 percent of the influent phosphorus estimated for each scale of application.

OVERLAND FLOW

Overland flow is a natural treatment system which relies on physical, chemical and biological processes to perform the desired treatment functions. Because overland flow technology has been shown to be effective in removing nutrients from treated wastewater effluents, it has been proposed as a potential treatment method for removing phosphorus from EAA drainage water.

Overview of Technology

Overland flow is routinely implemented for the treatment of municipal and industrial process wastewater effluent streams. It has not found widespread application for the treatment of stormwater runoff. The overland flow process was developed to overcome the limitations to land treatment that are created by soil types of low permeability.

In traditional overland flow treatment, effluent applied to the top of a graded slope flows in a thin film over a vegetated surface and is collected at the bottom of the slope. Distribution of the water onto the overland flow slopes can be accomplished by surface methods, low-pressure nozzles, or sprinklers. The typical application rate for an overland flow system in Florida, based on operational data from existing systems, is 0.2 cubic meters per hour per meter of slope width. This equates to 16.1 gallons per hour per foot of slope width. Typical slope length is 150 feet. Slope lengths greater than 150 feet are generally not implemented because of channelization problems.

Overland flow systems operate to reduce suspended and dissolved constituents by physical, chemical, and biological means. The removal of various constituents occurs predominantly in the organic mat on the soil surface. From a process control standpoint, it is desirable to operate an overland flow system at a constant application rate and application period, particularly where flow equalization is feasible. Flow recirculation is used to keep the slopes moist during periods of low rainfall or when flow equalization cannot be provided.

The major mechanisms responsible for phosphorus removal by overland flow include sorption on surface soils, precipitation as insoluble complexes of calcium, iron and aluminum, and plant uptake. When low-permeability soils are present near the ground surface, as is the case for most overland flow systems, much of the applied water flows over the surface and does not come in contact with the soil matrix and the phosphorus adsorption sites. As a result of this limited soil contact, operational data from existing overland flow systems indicate that phosphorus removal efficiencies generally range from 40 to 60 percent, averaging about 50 percent. Consistent removal rates of greater than 50 percent have not been demonstrated in full-scale operating overland flow systems.

Overland flow systems are generally operated 5 to 7 days per week, or 12 hours per day. The vegetation planted on the slopes is moisture tolerant but cannot remain inundated continuously. Typically, when overland flow systems are used to treat wastewater streams, the continuous flows are alternated between treatment areas to allow them to periodically dry out and to reduce stress on the vegetation. Because of the irregular nature of stormwater runoff, it is assumed that ample opportunities will be available between runoff events for the system to recover. It is also required that water circulation systems be installed to allow for irrigating the slopes during dry periods.

Operation and maintenance requirements consist of mowing to maintain a vigorous vegetative cover to discourage the growth of woody species and periodic inspection of the slope to ascertain the general health of the cover crop and the physical integrity of the slope. Harvesting vegetation from the slope removes phosphorus from the system. Some moisture-tolerant pasture grasses perform the treatment function acceptably and can be harvested as hay. Typical problems encountered include the formation of channels down the slope, nutrient deficiencies (particularly potassium), and pest infestation. Excess vegetative material deposits resulting from mowing need to be removed. Equipment used for maintenance should be equipped with flotation tires to minimize the creation of ruts on the slope.

The effluent often is discharged to adjacent surface waters. Systems that receive stormwater or agricultural drainage water will likely require construction and surface water management permits but not an NPDES permit. Systems that receive process water from a point source such as a sugar mill would have an additional requirement to obtain an NPDES permit.

<u>Basis of Evaluation</u>

It is possible to construct an overland flow system at all scales of application. However, overland flow systems have been constructed to treat wastewater flows up to only about 3 mgd. The design methodology for these systems is based primarily on suggested hydraulic application rates for various influent qualities based on previous experience with constructed systems.[12,52] In this evaluation, systems have been sized for all scales of application assuming an application rate of 16.1 gallons per hour per foot of slope width and a slope length of 150 feet. Currently there is no specific methodology for sizing these systems based on a target phosphorus removal rate. Furthermore, it is doubtful that overland flow treatment, by itself, can reduce TP concentrations in discharges from the EAA to 0.05 mg/l. Therefore, for this Phase I evaluation, overland flow treatment systems were sized to accommodate peak flows at all scales of application, and treatment area requirements were assumed to be the same for all three levels of phosphorus removal. This resulted in the technology receiving a higher rating for phosphorus removal capability as the removal level decreased from 75 percent to 25 percent.

Determination of required treatment area was based on the maximum depth of flow over the treatment slopes that could be accommodated without risk of major damage (rutting, erosion, loss of vegetation, etc.). It was assumed that a well-constructed system could handle twice the design flow depth. Therefore, design treatment capacity was assumed to be one-half of the peak flow rate at all scales of application. At the basin scale, design flow capacity would be about 1,200 mgd. At the subbasin, farm, and point source scales, treatment capacities would be about 120 and 17 mgd, respectively. Treatment capacity at the point source scale was assumed to be 15 mgd, equivalent to the maximum month flow rate. It was further assumed that no flow equalization would be provided and that flows in excess of the design treatment capacity would pass through the system and receive a reduced level of treatment.

Based on the assumed application rate of 16.1 gallons per hour per foot of slope width, approximately 2,000 miles of overland flow treatment area would be required to accommodate flows from the entire EAA. This amounts to about 36,000 acres of land for treatment areas alone. Additional land area, estimated to be about 33 percent of the treatment area, is required for buffer zones, support facilities (pumping stations, maintenance, etc.), access roads, and buildings. It was assumed that water for low flow recirculation could be withdrawn directly from canals and that no large on-site reservoirs would be required.

Experience with existing systems has shown that construction costs for overland flow systems range from about $8,000 to $12,000 per acre of slope depending on site conditions and the size of the treatment area. In this analysis, construction costs were estimated on the basis of $8,000 per acre of required treatment area. This cost was assumed to include the cost of all support facilities, including roads, buildings, and harvesting equipment. Additional costs were allocated for pumping facilities to convey water to the treatment slopes, land acquisition, and permitting and design.

The flow rates, land area requirements, and capital costs used in the evaluation of the overland flow treatment technology are summarized in Table 3-16.

Evaluation Results

Exhibit 3-16 shows the ratings given to overland flow at the various scales of application and phosphorus removal. The technology received its highest ratings at the point source scale and its lowest ratings at the farm scale.

Overland flow systems have reasonable phosphorus removal capability, particularly at the smaller scales of application and lower removal percentages. As was stated previously, phosphorus removal efficiencies of greater than 50 percent have not been demonstrated consistently in overland flow systems. Excess flows that are routed through the system would receive minimal treatment due to limited contact with the soil matrix. For excess flows to receive adequate contact for even a 50 percent phosphorus removal efficiency, temporary storage of waters and subsequent application of the system during periods of flow which are below design levels would be required. Incorporation of storage for flow equalization would provide greater confidence in the phosphorus removal capabilities of the system but would do so at significant additional costs and land requirements.

Implementation of overland flow systems throughout the EAA by 1997 is questionable. Significant site assessment work must be accomplished before design criteria for individual projects can be finalized. Flow equalization would result in improved hydroperiod management at all scales of application but was not considered as part of this evaluation. Operational impacts to the Central and South Florida Flood Control Project should be minimal. Construction and stormwater management permits would be required at all scales of application. An NPDES permit probably would be required for point source applications.

Table 3-16 Basis of Evaluation for Overland Flow

Parameter	Scale of application							
	Basin		Subbasin		Farm		Point source	
	Scale unit	Total EAA	Scale unit	Total EAA	Scale unit	Total EAA	Scale unit	Total EAA
Design flow, mgd								
25 percent P removal	1,200	4,800	120	4,800	20	3,460	15	105
50 percent P removal	1,200	4,800	120	4,800	20	3,460	15	105
75 percent P removal	1,200	4,800	120	4,800	20	3,460	15	105
Land area, acres								
25 percent P removal	12,000	48,000	1,200	48,000	220	38,000	155	1,100
50 percent P removal	12,000	48,000	1,200	48,000	220	38,000	155	1,100
75 percent P removal	12,000	48,000	1,200	48,000	220	38,000	155	1,100
Capital cost,[a] million dollars								
25 percent P removal	154	616	17	680	3.7	640	3.4	24
50 percent P removal	154	616	17	680	3.7	640	3.4	24
75 percent P removal	154	616	17	680	3.7	640	3.4	24

[a] 1992 dollars.

Exhibit 3-16 Phase I Evaluation Ratings for Overland Flow

Criterion	Criterion weighting[a]	Scale of application/level of phosphorus reduction[b]											
		Drainage basin			Subbasin			Individual farm			Point source		
		25	50	75	25	50	75	25	50	75	25	50	75
Phosphorus removal capability	3	8/24	5/15	2/6	8/24	5/15	2/6	8/24	5/15	2/6	9/27	7/21	5/15
Implementation schedule	2	4/8	4/8	4/8	4/8	4/8	4/8	4/8	4/8	4/8	5/10	5/10	5/10
Hydroperiod impact	2	7/14	7/14	7/14	7/14	7/14	7/14	7/14	7/14	7/14	6/12	6/12	6/12
Impact on C&SF Project	2	8/16	8/16	8/16	8/16	8/16	8/16	8/16	8/16	8/16	8/16	8/16	8/16
Permitting requirements	2	6/12	6/12	6/12	6/12	6/12	6/12	6/12	6/12	6/12	4/8	4/8	4/8
Previous application of technology	2	7/14	7/14	7/14	7/14	7/14	7/14	7/14	7/14	7/14	7/14	7/14	7/14
Capital cost	1	2/2	3/3	3/3	2/2	3/3	3/3	3/3	4/4	4/4	5/5	7/7	7/7
O&M requirements	1	5/5	5/5	5/5	4/4	4/4	4/4	3/3	3/3	3/3	6/6	6/6	6/6
Economic impacts	1	5/5	5/5	5/5	5/5	5/5	5/5	6/6	6/6	6/6	8/8	8/8	8/8
Total		100	92	83	99	91	82	100	92	83	106	102	96

[a] Criteria directly related to satisfying provisions of SWIM Plan receive a weighting of 2 or 3; all other criteria receive a weighting of 1.
[b] Phosphorus reduction levels of 25, 50 and 75 percent of the influent phosphorus estimated for each scale of application.

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High rate overland flow systems (up to 3 mgd) have been demonstrated extensively for wastewater treatment. Capital costs at all but the point source scale are estimated to be substantially higher than the wetlands base case alternative. An overland flow system at the point source scale would be expected to have lower capital costs than the base case wetlands system because it would be treating a waste stream with proportionally lower flows and higher phosphorus concentrations than at the other scales of application. Because of improved equipment logistics, the technology scored higher with respect to operation and maintenance requirements at the basin and subbasin scales of application. Land area requirements for overland flow systems were found to be higher than for the base case wetlands systems at the basin, subbasin, and farm scales, but less at the point source scale.

Discussion of Evaluation Results

Overland flow systems have the potential to remove phosphorus from EAA drainage waters and point sources but probably are not capable of meeting the treatment goals of the SWIM Plan by themselves. These systems generally are not constructed with the purpose of removing phosphorus efficiently. It is questionable as to how consistent or how long the phosphorus removal capability will last. Also, application of the technology at the basin and subbasin scale has never been attempted, creating additional uncertainty about phosphorus removal performance on large projects. In contrast, applications at the farm and point source scales have demonstrated reasonable phosphorus removal capability. At all scales, operation and maintenance of overland flow systems, which includes recirculation pumping, mowing, and slope maintenance, is more intensive than for the base case wetlands systems. Operation and maintenance becomes more difficult and costly at the subbasin and farm scales of application due to equipment logistics and the number of systems to be operated and maintained.

In summary, overland flow systems have potential for removing phosphorus from EAA drainage waters and point source discharges. Because of land area requirements, they are better suited for small-scale applications with relatively uniform flows and moderate to high influent TP concentrations. Point source applications, such as polishing treated effluent from small wastewater treatment plants in the EAA, may be particularly attractive. On a large scale, the technology offers no advantages over the base case wetlands systems in terms of phosphorus removal capability, land area requirements, or capital cost.

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CHAPTER 4

ANALYSIS OF PHASE I EVALUATION RESULTS

CHAPTER 4

ANALYSIS OF PHASE I EVALUATION RESULTS

Presented in this chapter is a comparative analysis of the Phase I evaluation results for screening of the alternative treatment technologies. The top rated technologies in each scale of application are identified. Other technologies that may warrant further consideration for site-specific application in the EAA are also noted.

SUMMARY OF PHASE I EVALUATION RATINGS

A summary of the Phase I evaluation ratings for the alternative treatment technologies is presented in Exhibit 4-1. The rating points in Exhibit 4-1 reflect the totals given to each of the technologies in Exhibits 3-1 through 3-16 in Chapter 3. The ratings provide an indication of how the various technologies were scored against the set of nine evaluation criteria as a whole. The ratings also provide an indication of how each technology scored in relation to the other technologies evaluated.

SCREENING OF TECHNOLOGIES

An important objective of the Phase I evaluation was to identify those technologies that rate highest overall at each of the four scales of application and the three levels of phosphorus reduction being considered for treatment facilities in the EAA. Consequently, the composite ratings illustrated in Exhibit 4-1 serve as the primary means of identifying the most promising technologies. At each scale of application, a group of three to five technologies were rated higher than the others. These top rated technologies, therefore, were considered first when selecting the technologies to be evaluated in detail in Phase II.

In addition to the several top rated technologies in each scale of application, consideration was also given to other technologies that were rated lower overall but offered particular advantages to the EAA in terms of (1) reduced capital costs or (2) lower land area requirements compared with the Stormwater Treatment Areas (STAs) contained in the current SWIM Plan. These criteria were assigned a low weighting factor in the Phase I evaluation process partly because they could not be quantified with a high degree of accuracy at the screening level. As a result, high scores against these criteria did not necessarily mean a technology would score well overall. Nevertheless, the initial capital cost of implementation and the number of acres that must be taken out of agricultural production are and will continue to be two of the most important factors in the selection of treatment technologies for the EAA. Technologies that offer significant benefits in these areas should not necessarily be eliminated from further consideration at this initial screening stage of the evaluation process.

Exhibit 4-1 Phase I Evaluation Ratings Summary

Technology	Scale of application/level of phosphorus reduction											
	Drainage basin			Subbasin			Individual farm			Point source		
	25	50	75	25	50	75	25	50	75	25	50	75
Chemical treatment	104	97	85	104	97	84	107	101	90	108	104	97
Limerock sorption	69	62	52	70	63	53	80	71	63	87	74	69
Sedimentation in limestone borrows	101	95	89	101	95	87	103	98	91	108	104	100
Percolation ponds	88	80	72	88	80	72	90	84	78	117	110	100
Deep well injection	78	69	59	83	79	72	89	88	82	124	123	121
Aquifer storage and recovery	73	--[a]	--	78	73	--	82	77	--	83	78	--
Water quality/supply diversion plan	78	53	--	--	--	--	--	--	--	--	--	--
Algal turf scrubbers	77	70	63	76	70	63	85	79	72	85	80	73
Nutrient management system	94	87	77	92	85	75	86	79	70	99	93	87
Ozone treatment	63	60	57	63	60	57	63	60	57	65	62	59
Sediment dredging	118	--	--	--	--	--	--	--	--	--	--	--
Wetlands	131	127	111	129	125	109	122	119	103	121	119	103
Managed wetlands	129	127	121	127	124	119	117	107	97	119	113	107
Direct filtration	118	116	112	114	111	107	104	98	91	118	115	112
Barge treatment	60	56	54	60	56	54	--	--	--	--	--	--
Overland flow	100	92	83	99	91	82	100	92	83	106	102	96

[a] "--" indicates technology not evaluated at this scale of application or level of phosphorus reduction.

Presented in Table 4-1 is a summary of the technologies that are proposed for detailed evaluation at each of the four scales of application in the EAA. Two categories of technologies are indicated. The top rated technologies are those technologies which scored the highest overall against the set of nine evaluation criteria. Generally, these technologies received a total score of 100 points or more in the numerical ratings.

Technologies shown in the conditional category have potential application in the EAA but did not necessarily score as high as the technologies in the top rated category. Generally, the conditional technologies depend on further definition of waste stream, permitting requirements, or site characteristics to determine feasibility. Additional data and information relevant to the potential applicability of these technologies to the EAA may be available in the next several months before the Phase II evaluations are completed.

Table 4-1 Technologies Proposed for Detailed Evaluation

Technology classification	Scale of application			
	Drainage basin	Subbasin	Individual farm	Point source
Top rated	Wetlands Managed wetlands Direct filtration	Wetlands Managed wetlands Direct filtration	Wetlands Managed wetlands Chemical treatment[a]	Wetlands Managed wetlands Direct filtration Deep well injection Percolation ponds
Conditional	Chemical treatment[a] Sediment dredging[b]	Chemical treatment[a]	Overland flow Aquifer storage and recovery	Chemical treatment[a] Overland flow

[a] Chemical treatment could also involve use of limestone borrow areas for sedimentation, if appropriate.
[b] One-time dredging of District canals; not an ongoing treatment process.

Those technologies not included in Table 4-1, either as a top rated or conditional technology, do not warrant detailed evaluation at this time. Many of these technologies, however, may be cost-effective as supplements to or replacements for on-farm best management practices (BMPs), which must reduce phosphorus loads from the EAA by a minimum of 25 percent. Ongoing research and development activities and pilot plant demonstration projects may show some of these other technologies to be effective in removing phosphorus, particularly at the farm scale where innovative technologies usually can be best applied.

Basin Scale Application

At the basin scale of application, the three top rated technologies are wetlands (STAs), managed wetlands, and direct filtration. These three technologies scored significantly higher than the others primarily because of their phosphorus removal capability, their ability to be implemented by 1997, and the fact that they have all been successfully implemented previously at full scale for treatment of stormwater or wastewater treatment plant effluent.

No one technology has a clear advantage over the other two. The managed wetlands and direct filtration alternatives have an advantage over the STAs in terms of phosphorus removal capability. The managed wetlands system, as developed for this evaluation, uses somewhat more land than the STAs. The direct filtration alternative uses significantly less land. Both the direct filtration alternative and the managed wetlands alternative have capital costs similar to the STAs. Implementation schedule favors direct filtration, since less land needs to be purchased, construction time will be less, and start-up will be faster. However, conceptual design of the STAs has already been accomplished and the permitting process has already been initiated.

Two other technologies may also be worthy of further consideration. The performance of chemical treatment in canals is somewhat suspect due to uncertainties over sludge settleability and sludge storage volume requirements. However, should ongoing research by the Florida Sugar Cane League (FSCL) provide additional data resolving these questions, chemical treatment may be a viable technology at the basin scale, particularly if limestone borrow areas are located nearby for use as settling ponds. In this regard, it may be possible to negotiate with the Florida Department of Transportation to locate borrow areas for future road construction near treatment sites.

The other technology which may have application at the basin scale is sediment dredging. Although it can only achieve part of the phosphorus reduction goal, sediment dredging can be implemented quickly and at reduced cost compared with the other alternatives. It also requires no long-term utilization of land. If a meaningful reduction in phosphorus load can be projected as the result of water quality studies currently being planned by the District, sediment dredging may well be one of the more attractive technologies from the standpoint of dollars spent per pound of phosphorus removed.

Subbasin Scale

The treatment technologies most applicable at the drainage basin scale would also be the most applicable at the subbasin scale. The major differences involved would be the increased cost and permitting requirements and the potentially longer implementation schedule associated with the larger number of treatment facilities. This resulted in slightly lower ratings for most technologies at the subbasin scale as compared with the drainage basin scale. However, no change in technology rankings resulted from these reductions in individual criterion ratings.

Individual Farm Scale

At the individual farm scale, the three top rated technologies were wetlands, managed wetlands, and chemical treatment. Direct filtration and overland flow also received high scores. Of these two other technologies, overland flow is the most appropriate to consider further at the farm scale. Direct filtration becomes much more costly when many small treatment facilities must be constructed. Overland flow, on the other hand, is compatible with agricultural operations in that harvesting of a grass crop would be an integral component of the treatment process. If used in conjunction with chemical treatment at the farm scale, land area requirements could be reduced significantly. However, applicability would need to be determined on a case-by-case basis depending on the waste stream and site characteristics involved.

Another technology which may warrant further consideration at the farm scale is aquifer storage and recovery (ASR). Although this technology did not score as well as some of the other technologies, primarily because of uncertainties over permitting requirements and implementation schedule, it is a potentially significant component of a regional water resources management program for the EAA. At the farm scale, it also has the potential to reduce phosphorus loads by reducing the amount of drainage water pumped off-farm. If geologic and hydrogeologic conditions are found to be favorable, and existing permitting constraints can be eased, it is possible that ASR could be applied in a manner similar to an on-farm BMP to reduce phosphorus loads on downstream treatment facilities.

Point Source Scale

For point source applications, emphasis must be placed on the ability of the treatment technologies to remove 75 percent (or more) of the phosphorus from the process wastewater. Mixes of technologies are not nearly as important for treatment of point source discharges as they might be for treatment of drainage water from the EAA.

The five top rated technologies for treatment of point source discharges are wetlands, managed wetlands, direct filtration, deep well injection, and percolation ponds. In addition, chemical treatment could be a viable option, particularly if limestone borrow areas are located nearby, and overland flow could be an attractive alternative for polishing effluent from other treatment processes.

This evaluation has focused on discharges from sugar mills as the predominant point sources of phosphorus in the EAA. Each mill has different wastewater characteristics in terms of flow and constituent concentrations and different site characteristics in terms of soils, land area availability, and proximity to canals. In addition, there are numerous other point sources throughout the EAA which might not be as significant individually, with respect to phosphorus discharges, as the sugar mills, but could be significant when considered in an aggregate sense. Among the other point sources that may need to be considered during the detailed evaluation of treatment technologies are municipal wastewater treatment plants, small package wastewater treatment plants, fertilizer plants, and vegetable packaging plants. Because of the wide range of waste stream characteristics associated with the various point sources in the EAA, any of the technologies identified in Table 4-1 could be appropriate for point source application depending on site-specific conditions and the level of treatment that is required.

RECOMMENDATIONS FOR PHASE II EVALUATION

Based on the results of the Phase I evaluation as documented in this report, it is recommended that the District proceed with detailed evaluation of the top rated treatment technologies shown in Table 4-1 for each scale of application. These technologies should be applied to specific waste streams in the EAA for the Phase II evaluation to better define the economic and noneconomic differences between them. Those technologies listed as "conditional" in Table 4-1 should not be included in the Phase II evaluation unless additional data or information supporting their capability to meet the requirements of the SWIM Plan becomes available.

APPENDIX A

DESCRIPTION SHEETS FOR PHASE I EVALUATION CRITERIA

PHASE I EVALUATION CRITERIA

Criterion: Phosphorus Removal Capability

Criterion Weighting: 3

Range of Acceptability for Technology Rating

Description	Recommended rating
Proposed technology capable of reducing phosphorus loads by required percentage on a consistent (monthly average) basis.	8-10
Proposed technology capable of reducing phosphorus loads by required percentage on a yearly average basis.	5-7
Proposed technology marginally capable of reducing phosphorus loads by required percentage.	1-4

Criterion Discussion: The SWIM Plan requires that discharges to the Everglades Protection Area reduce the total phosphorus load on an average annual basis. This criterion measures the capability of the technologies to satisfy this important performance objective. Technologies have different demonstrated capabilities to achieve phosphorus levels depending on the total load reduction desired. Those technologies which reduce TP on a consistent basis rate higher against this criterion than technologies that cannot achieve such phosphorus reduction consistently.

PHASE I EVALUATION CRITERIA

Criterion: Implementation Schedule

Criterion Weighting: 2

Range of Acceptability for Technology Rating

Description	Recommended rating
All elements of alternative implementable prior to 1997.	8-10
All elements of alternative implementable by 1997.	5-7
Minor elements of alternative not implementable by 1997.	3-4
Major elements of alternative not implementable by 1997.	1-2

Criterion Discussion: The SWIM Plan stipulates that interim phosphorus loads to the Everglades Protection Area be attained by July 1, 1997. This criterion evaluates the capability of a technology to achieve this objective by assessing when the various project elements can be realistically brought on-line. Technologies that can be implemented quickly and placed into operation prior to the 1997 deadline rate higher than those that cannot.

PHASE I EVALUATION CRITERIA

Criterion: Hydroperiod Impact

Criterion Weighting: 2

Range of Acceptability for Technology Rating

Description	Recommended rating
Implementation of technology results in significant improvement to the quantity, timing and distribution of flows entering the EPA.	9-10
Implementation of technology results in an improvement to flows entering the EPA.	7-8
Implementation of technology results in no changes to flows entering the EPA.	5-6
Implementation of technology results in significant seasonal decreases to flows entering the EPA.	3-4
Implementation of technology results in significant year-round decreases to flows entering the EPA.	1-2

Criterion Discussion: The quantity, distribution, and timing of water flow to the Everglades Protection Area (EPA) is critical to maintaining and restoring native floral and faunal communities. The SWIM Plan requires that actions be taken to restore suitable hydroperiod in the EPA in conjunction with measures to reduce phosphorus loads. This criteria measures the capability of a technology to maintain hydroperiod in the EPA.

PHASE I EVALUATION CRITERIA

Criterion: Operational Impact on C & SF Project

Criterion Weighting: 2

Range of Acceptability for Technology Rating

Description	Recommended Rating
Alternative results in no significant changes to the operational plan for C & SF Project.	8-10
Alternative results in minimal changes to operational plan for C & SF Project.	4-7
Alternative requires congressional action to implement.	1-3

Criterion Discussion: This criterion measures the degree of impact an alternative has on the facilities and goals of the Army Corps of Engineer's Central & South Florida Project. Some Alternatives may impact flood protection and/or water supply goals of the Project. Significant impacts on the goals of the C & SF Project may require Congressional action.

PHASE I EVALUATION CRITERIA

Criterion: Permitting Requirements

Criterion Weighting: 2

Range of Acceptability for Alternative Rating

Description	Recommended rating
Implementation of technology requires permits related only to the initial construction of improvements.	8-10
Implementation of technology requires permits related to initial construction of improvements and Florida DER operating permits.	5-7
Implementation of technology requires permits related to initial construction of improvements, Florida DER operating permits and USEPA operating permits (NPDES).	3-4
Implementation of technology requires a waiver or exemption from existing regulations.	1-2

Criterion Discussion: This criterion measures the anticipated regulatory permitting requirements of a technology. Some technologies will require construction permits only, while others will probably require operating permits. In a few cases, waivers or exemptions from existing regulations might be required in order to implement a technology. Technologies requiring only construction permits are the most preferable with respect to this criterion. Technologies that require operating permits are less desirable because of the ongoing regulatory monitoring and compliance activities that must be accomplished. Technologies that require waivers or exemptions are the least desirable from a permitting perspective. In assigning ratings to technologies, the anticipated difficulty in obtaining permits should also be considered. Therefore, a technology that requires few permits that are difficult to obtain could receive a lower rating than a technology that requires a greater number of permits that are easier to obtain.

PHASE I EVALUATION CRITERIA

Criterion: Previous Application of Technology

Criterion Weighting: 2

Range of Acceptability for Technology Rating

Description	Recommended rating
Technology has been successfully applied at full scale for treatment of stormwater or agricultural drainage.	10
Technology has been successfully applied at full scale in water and wastewater treatment applications.	7-9
Technology has been successfully field tested at full scale for the treatment of stormwater or agricultural drainage.	5-6
Technology has been demonstrated through pilot testing in the field.	3-4
Technology has been demonstrated at bench scale in the laboratory.	1-2

Criterion Discussion: Few, if any, treatment technologies have been applied to stormwater or agricultural drainage at sizes and loading rates comparable to those required by the SWIM Plan for protection of the Everglades. However, some technologies have been used in similar full scale applications while some are just now being researched in the laboratory prior to field testing. It is important that the treatment technologies to be implemented have documented evidence that they will be successful in satisfying the performance objectives of the SWIM Plan. Technologies with successful previous applications at full scale on stormwater or agricultural drainage will have the best documented evidence and, therefore, will rate the highest against this criterion.

PHASE I EVALUATION CRITERIA

Criterion: Capital Cost

Criterion Weighting: 1

Range of Acceptability for Technology Rating

Description	Recommended rating
Capital cost lower than the Base Case Alternative in the current SWIM Plan.	6-10
Capital cost of the Base Case Alternative.	5
Capital cost alternative higher than the Base Case Alternative.	1-4

Criterion Discussion: The estimated capital cost for construction of the alternative treatment technologies, including land purchase, design, equipment, materials for construction, etc., will be compared to the capital cost for the Base Case Alternative. Technologies with the lowest capital costs will be rated highest, while technologies with the highest capital costs will be rated the lowest.

PHASE I EVALUATION CRITERIA

Criterion: Operation and Maintenance Requirements

Criterion Weighting: 1

Range of Acceptability for Technology Rating

Description	Recommended rating
Operation and maintenance requirements less than the Base Case alternative in the current SWIM Plan.	9-10
Operation and maintenance requirements similar to those of the Base Case alternative.	8
Operation and maintenance requirements greater than the Base Case alternative.	1-7

Criterion Discussion: This criterion measures the degree of knowledge and effort necessary to properly operate and maintain the conveyance, storage and treatment facilities proposed for an alternative technology. Factors to be considered include total labor requirements, degree of operator training and certification (if any) required, diversity of skills required, specialized machinery or equipment required, degree of regulatory monitoring and reporting required, and sensitivity of treatment performance to a proper operation and maintenance program.

PHASE I EVALUATION CRITERIA

Criterion: Economic Impacts

Criterion Weighting: 1

Range of Acceptability for Technology Rating

Description	Recommended rating
Total farm land area required:	
Less than 500 acres	10
500 to 25,000 acres	8
25,000 to 45,000 acres	6
45,000 to 65,000 acres	4
65,000 to 85,000 acres	2
Greater than 85,000 acres	1

Criterion Discussion: This criterion uses private land area requirements to measure the economic impact that the various technologies will have on the EAA and the Lower East Coast. As a screening tool the economic impact is based on a linear relationship beginning with 500 acres.

Table 3-9 Basis of Evaluation for Nutrient Management System

Parameter	Scale of application							
	Basin		Subbasin		Farm		Point source	
	Scale unit	Total EAA	Scale unit	Total EAA	Scale unit	Total EAA	Scale unit	Total EAA
Design flow, mgd								
25 percent P removal	1,200	4,800	120	4,800	20	3,400	15	105
50 percent P removal	1,200	4,800	120	4,800	20	3,400	15	105
75 percent P removal	1,200	4,800	120	4,800	20	3,400	15	105
Dike length, miles								
25 percent P removal	41	164	7	280	2	346	8	56
50 percent P removal	47	188	7	280	2	346	10	70
75 percent P removal	60	240	9	360	2	346	11	77
Land area required, acres								
25 percent P removal	4,691	18,765	563	22,518	92	15,966	521	3,649
50 percent P removal	5,630	22,518	676	27,022	111	19,159	626	4,379
75 percent P removal	7,037	28,148	844	33,777	138	23,948	782	5,473
Capital cost,[a] million dollars								
25 percent P removal	83	330	13	510	4	660	13	92
50 percent P removal	95	382	14	565	4	706	16	109
75 percent P removal	116	466	17	688	5	853	18	124

[a] 1992 dollars.